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Generative Suburban Frameworks: Emerging Architect-Guided Optimization Workflows Within Suburban Mass Production

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generative suburban frameworks

emerging architect - guided optimization workflows within suburban mass production

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By

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00 / acknowledgements

To my thesis advisor, David Newton, for sharing your breadth of disciplinary knowledge and your guidance throughout the development of this research.

To my past mentors, Jason Griffiths, Steve Hardy, and Michael Harpster, who fostered my interest in design and whose lasting impacts define the value of education.

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And most of all, to my parents, for their love and encouragement, their unconditional support, and endless patience.

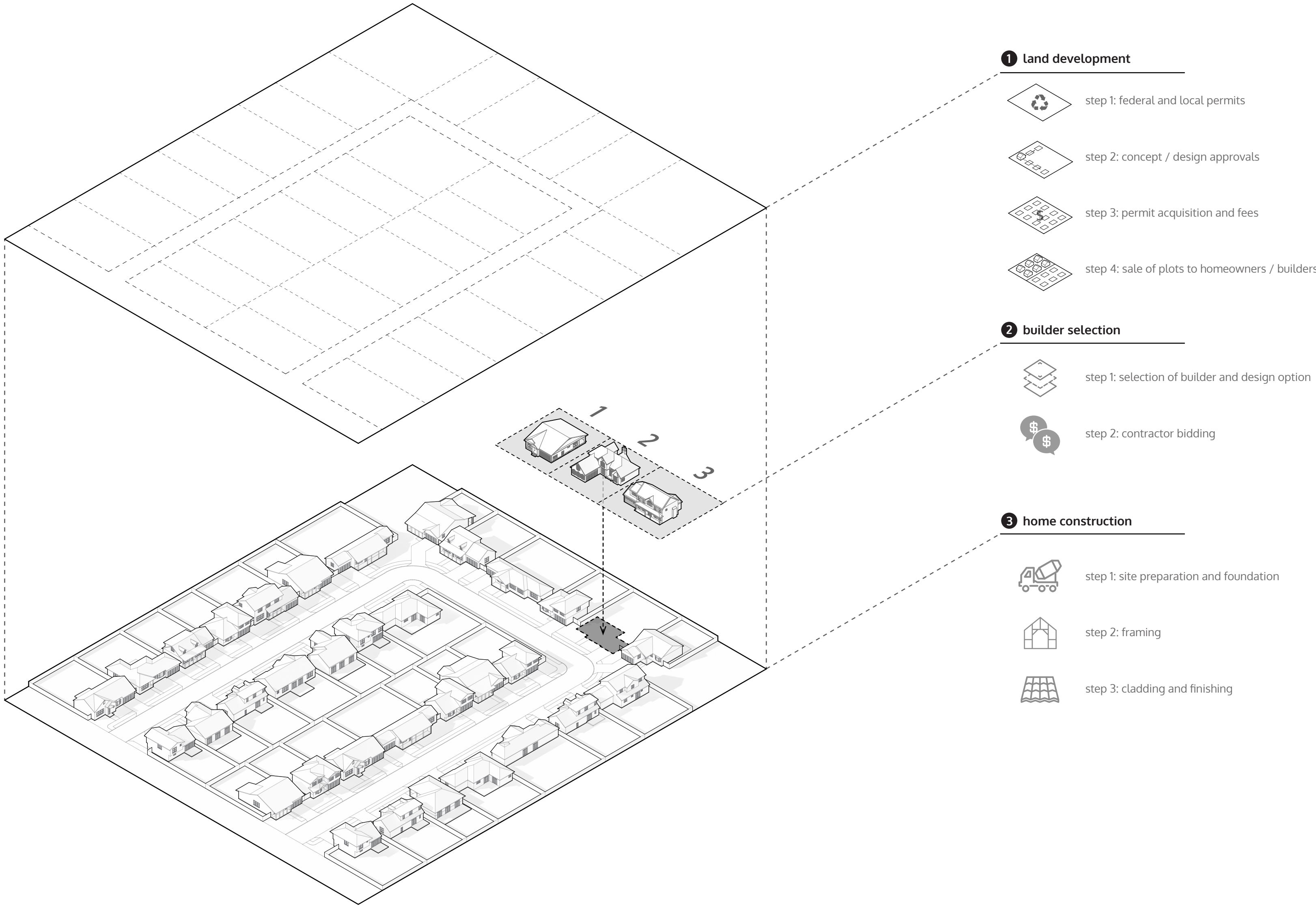
Thank you.

01 / abstract

The mass production of single-family housing has led to a number of overlooked design problems, including enormous physical footprints, subpar construction, and hastily installed infrastructure (Florida 2017). The continued growth of this development strategy has decreased the disparity of the building type, which also undergoes far less design consideration than other building typologies. Solutions to these issues have been oriented around concepts of modular construction and prefabricated elements. These ideas have typically remained in conceptual design stages, and when actualized they tend to lack the simplicity, speed, or cost of current residential construction practices. Additionally, several of these approaches could benefit from incorporating multi-objective optimization strategies as well as increasing the involvement of architects to improve design exploration and development. This thesis explores emerging architect-guided optimization processes and their capabilities within suburban mass production, to create an algorithmic workflow that introduces a unique role of the architect and affords current construction speed coupled with design considerations that have been absent in normative residential design.

normative suburban development process

example single family housing development



02 / introduction

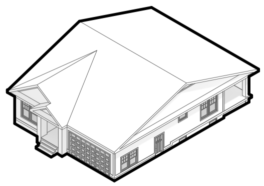
The current state of residential design is oriented around the concept of predesigned options that homeowners then elect to place on their property. These options are inherently structured and organized for speed of construction and lack the careful design consideration that goes into high-end residential projects. These include but are not limited to site context issues, user needs, energy use considerations, and the various theoretical design frameworks that are incorporated into large scale design. The continued use of this method of production has caused a continually reduced role of the architect within suburban housing, with architects only being involved in 1-2 percent of homes built today.

Previously, this system was advantageous in order to adjust to the increased demand for suburban living following postwar affluence in the 1950's. However, there are numerous negatives we suffer as a result of the mass production of suburban homes, for example; the vast majority of suburban homes perform below sustainable performance benchmarks (Center for Sustainable Systems 2018). Additionally, an estimated 8,000 pounds of waste is created in the construction of a 2,000 square foot home (Green Building Elements 2009) and since 1950, the average square footage of homes has nearly tripled while the average number of occupants has actually decreased. To add to this, the world population is expected to increase by a value of 2.3 billion by 2050 (Montgomery 2003), with an estimated 100 million of those people occupying the suburbs in the United States alone (Nelson 2013). With the effects of population growth and climate change becoming increasingly evident, how can architects be involved to improve the design of suburban homes while maintaining the high time and cost measures of present conditions?

Parallel to this housing phenomenon is the rapid rise of optimization within architectural workflows, as a tool to quickly incorporate desired objectives in architectural design and find optimal solutions to design problems. However, this process is not without limitations, as this approach is only able to find quantitative objectives with no consideration for qualitative objectives. Additionally, these approaches also reduce the role of the architect, as he or she would be limited to selecting optimized models or simply preparing a script to undergo the optimization. Additionally, many objective problems arise when the number of objective variables is greater than 3 and results in many issues. For example, the solution space can become too large for the algorithm to converge on optimal models, as the solution space increases exponentially with added objectives. The design of single - family homes undoubtedly requires for the consideration of numerous quantitative and qualitative objectives. How then, can optimization be rethought to expand designer engagement, reach solutions with more than 3 objectives, and evaluate qualitative goals?

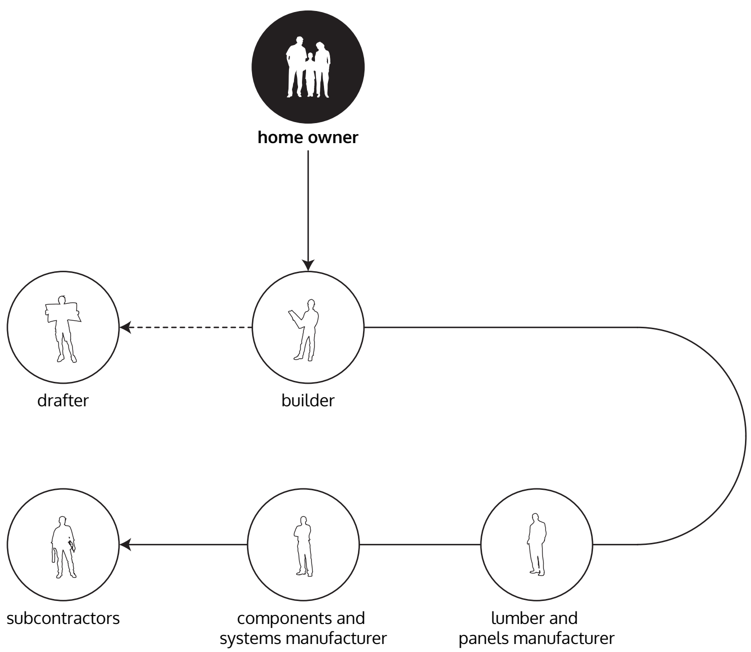
This thesis develops a generative framework that utilizes a unique architect-guided optimization workflow to approach these computational and suburban design issues. To account for the high number of decision variables associated with single-family housing, the architect guides the optimization by selecting the models that align with various qualitative objectives. The selection of models based on design qualities allows for the optimization search to be narrowed, reducing the number of possible solutions involved. This process adapts the normative suburban design approach of repeated floor plans to further involve the architect and allow variation in suburban models by adjusting the design to respond to various desired optimization objectives related to site, energy use, cost, user conditions, etc.

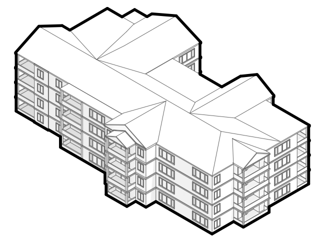
single family housing involving architects is estimated between just 1 and 2 percent of total construction



single family housing

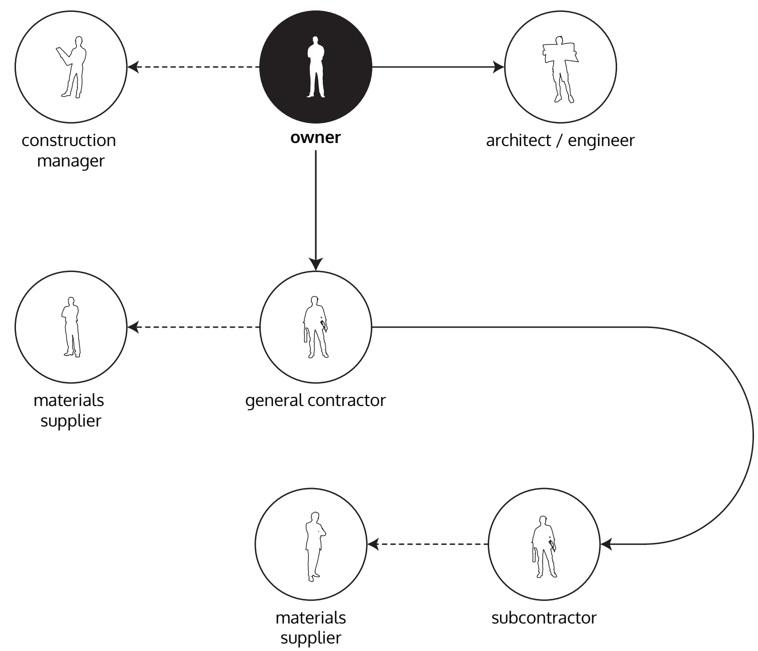
architects absent





commercial / multi-family housing

architects present



1 suburban homes are rarely designed for the needs of their user

-unique family models may face difficulty finding home designs that fit their needs

-since 1950, the average square footage of homes has nearly tripled while the average number of occupants has decreased

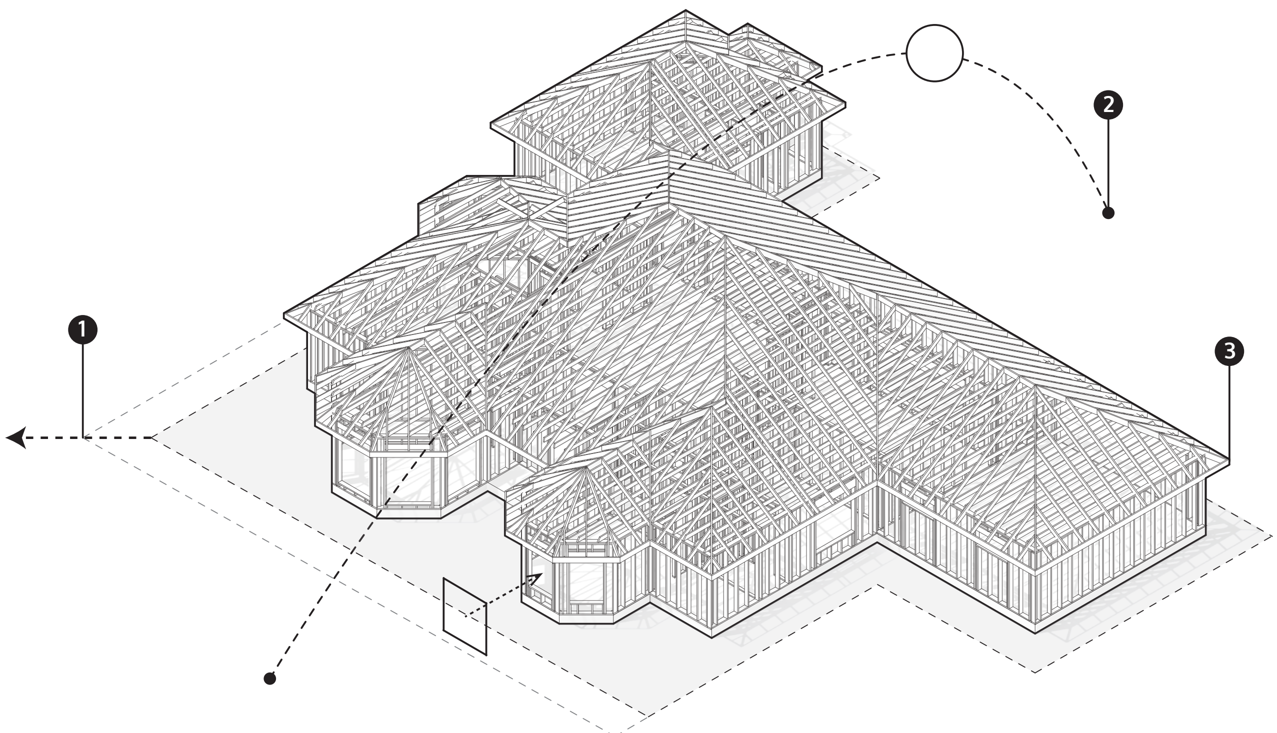
2 suburban homes maintain the same design regardless of their location or context

-the vast majority of suburban homes perform below sustainability benchmarks

-an estimated 8000 pounds of waste is produced in the construction of a 2000 sq ft home

3 normative home designs utilize a universal aesthetic, with little variation

-aesthetic options outside of the normative approaches are rare and likely to face criticism of surrounding homeowners



optimization as a potential method to reduce design costs

single - objective optimization

- architect's role limited to proparing weight of the optimization variables

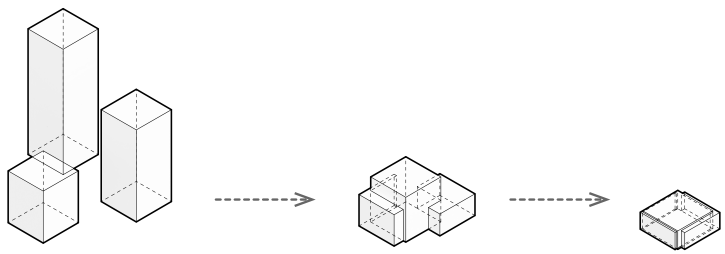
decision variables:

length, width, height

origin point

objective:

minimum possible volume



optimal model

lacks qualitative considerations

multi - objective optimization

- architect's role limited to selecting model from the pareto front

decision variables:

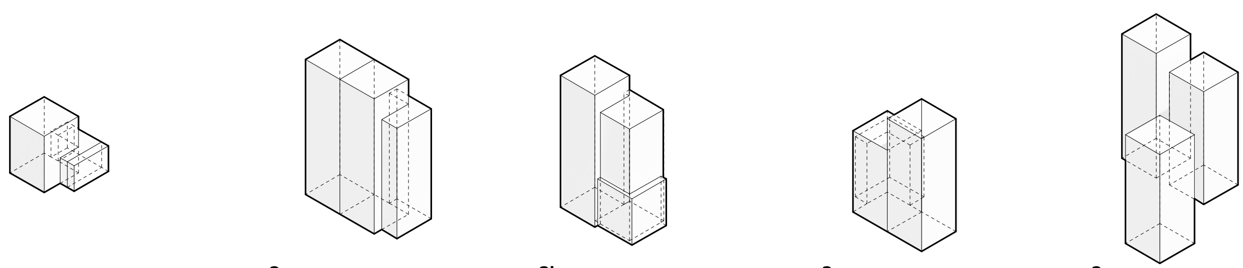
length, width, height

origin point

objectives:

maximum possible volume

minimum possible surface area



1
volume: 2
surface area: 45

2a
volume: 11
surface area: 160

2b
volume: 9.7
surface area: 150

2c
volume: 9.5
surface area: 150

3
volume: 18
surface area: 323

pareto - optimal data set

optimized models lack qualitative considerations

many - objective vs. multi - objective optimization

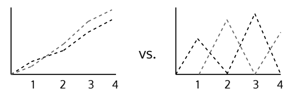
the design of a single family home requires numerous quantitative and qualitative goals.

Many - objective optimization problems (MaOPS) are those which result from a number of objective variables greater than 3 and results in difficulties to the existing multiobjective evolutionary algorithms, including cursed dimensionality, increased computational cost, and visualization of the dimensional tradeoff front.

10 x 10 = 100
10 x 10 x 10 = 1000
10 x 10 x 10 x 10 = 10000
10 x 10 x 10 x 10 x 10 = 100000

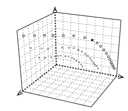
cursed dimensionality

Solutions are unlikely to converge within many objective problems due to the size of the solution space



computational cost

Many objective problems require great computational cost, making it computationally impossible to find optimal solutions within desired time frames



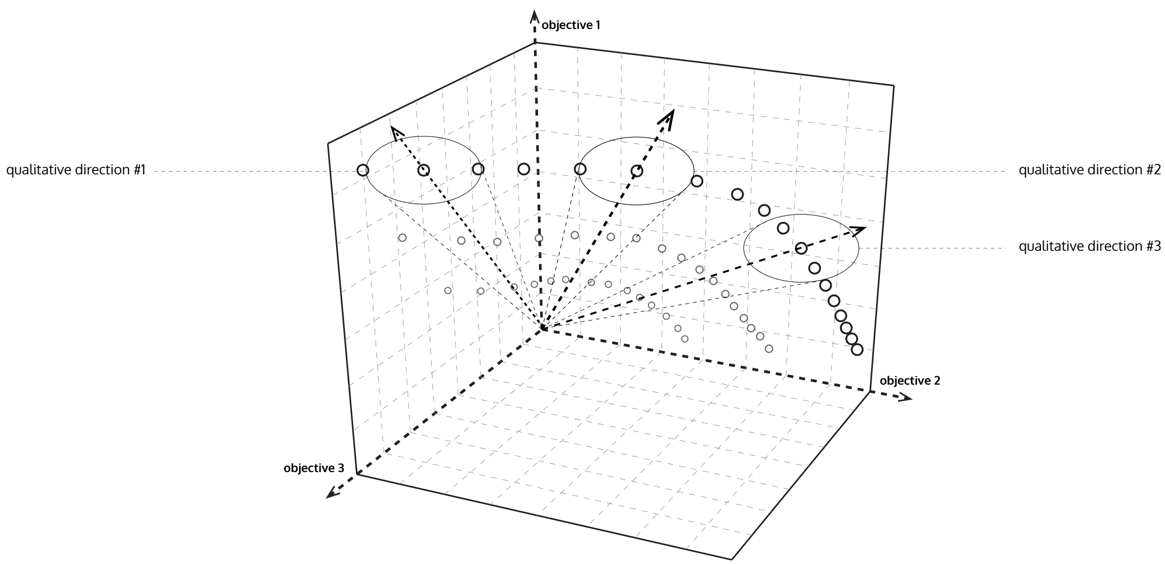
visualization of the dimensional trade off

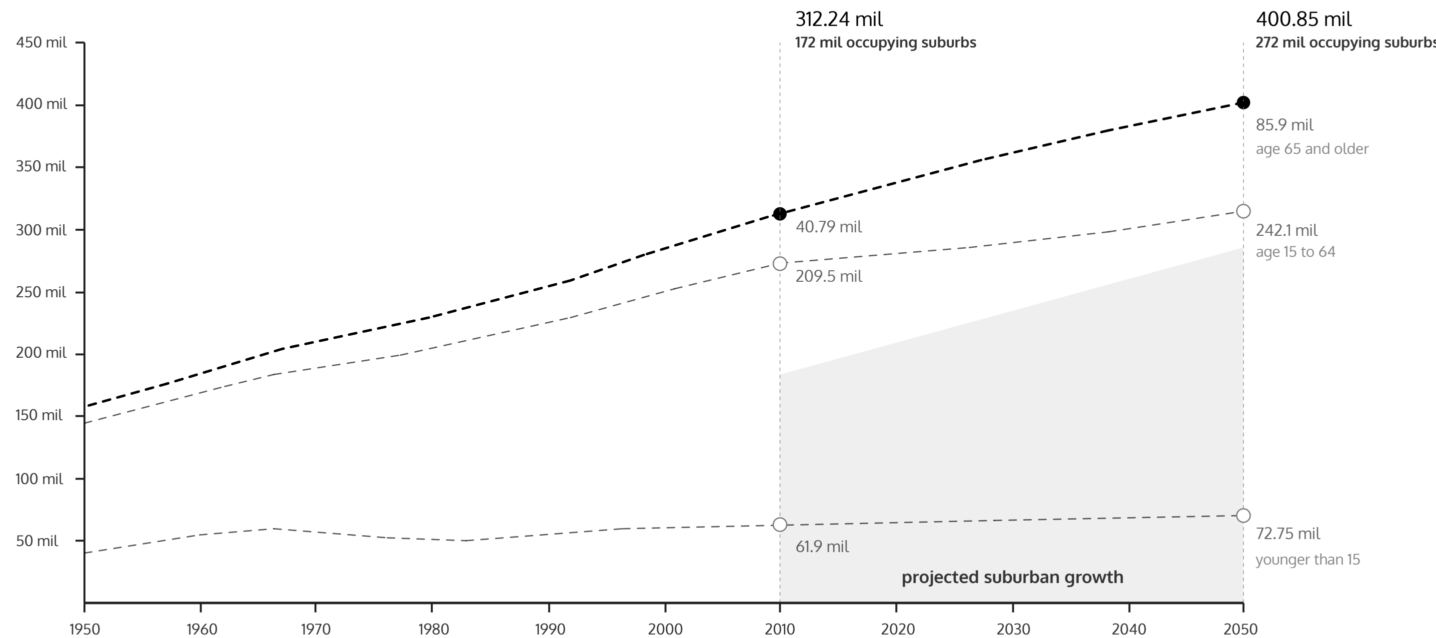
There is no easy or intuitive method to visually represent the Pareto front in MaOPS. This makes the selection of architecturally optimal solutions more difficult

how can optimization be rethought to expand designer engagement, reach solutions with more than 3 objectives, and evaluate qualitative design goals?

human component theoretically required for solution space reduction in MOPs:

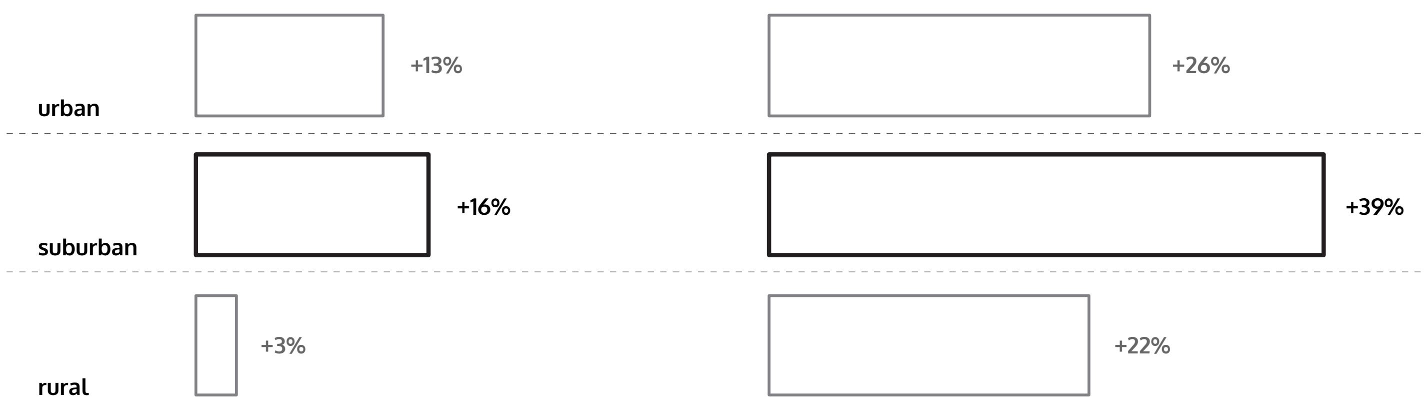
human components in multi objective optimization are able to guide the optimization through the incorporation of qualitative elements, thus reducing the solution space of the algorithm





how can architects be involved to improve the design of homes for the projected 100 mil set to occupy the suburbs by 2050?

estimates of the us population, by age, 1950 to 2050



suburbs are seeing greatest growth in population, especially in the elderly

percent change in population since 2000

percent change in population, age 65 and older since 2000

03 / background

normative residential design development:

The origin of current normative residential construction strategies in the suburbs of North America come from Bill Levitt in his developing of “Levittown”, America’s prototypical postwar planned community (Kelly 1950). Responding to increased demand from veterans and new federal supports, Levitt and a group of builder-developers modernized home building to achieve mass production. Using techniques pioneered by prewar builders, contractors streamlined home building by employing standardized parts and floor-plans, allowing subassembly of doors and windows, and subdividing labor to minimize the need for skilled or unionized workers (Hayden 2003). This caused the scale of home building to increase exponentially. Annual housing construction moved upward from 142,000 homes in 1944 to an average of 1.5 million per year in the 1950s (US Department of Labor 1960).

Contrary to Levitt’s consumerist strategies were those with increased design consideration, such as Frank Lloyd Wright’s Usonia concepts for low-cost housing. They challenged the notion of cladding a home in synthetic, off the shelf, and mass-produced product, claiming it only leads to placeless-ness and disconnection (Wright 1954). In order to compete with the cost and speed of their competitors, Usonian homes were built with no attics or basements, an efficient use of indoor and outdoor space, simple rooflines, and in-floor radiant heating (Reggey 2018). However, Wright was forced to waive his design fees for these homes as well as borrow materials from the sites of his larger projects in order to sell the Usonian homes at his desired price (Avery 2018). These cost issues restricted Wright’s housing concepts from taking hold as Levitt’s had.

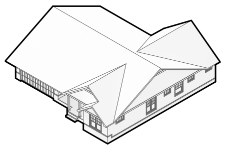
Following the development of these housing schemes, the decline of manufacturing coupled with the rise of service employment in the United States dramatically reshaped suburbia. In places like California, development schemes reached proportions that made even postwar developments like Levittown look small by comparison. By the early 21st century, the first national development firms were building tens of thousands of units per year, replicating standardized architecture and community planning across the United States (Wiese, Nicolaides 2017). By the peak of the housing bubble in 2005, the top five largest builders each closed on more than 30,000 houses for the year (Builder Magazine 2015). Their activity symbolized the dramatic expansion of suburban areas and rise in the suburban population in the U.S., with a majority of Americans living in suburbia by 2010. (Census Bureau 2010)

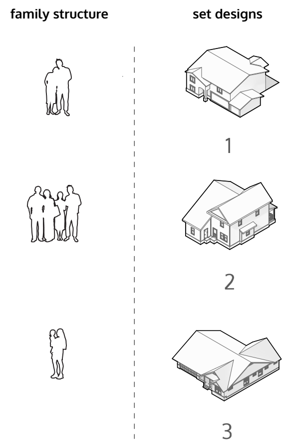
Current normative residential construction strategies were originally driven by social assumptions and a deep seeded campaign for conformity, privatization, and domesticity. Many of the early developers took advantage of this political and social climate, providing as little as they needed for as much profit as they could. Many of these qualities that drove development had negative effects (as described previously), which have opened our eyes on how the house can influence far more than we may have realized. Contrary to this movement, some designers emphasized the house as a valued object in of itself with embedded intentions and strategies. They aimed to design homes that had value beyond being a placeless shell to perform responsibly. Demographic changes, environmental issues, and a decrease in affordability have been identified as emerging and prevalent conditions in the suburbs today. How will, or should, these various conditions and new wave of homeowners impact the characteristics and design of suburbia?

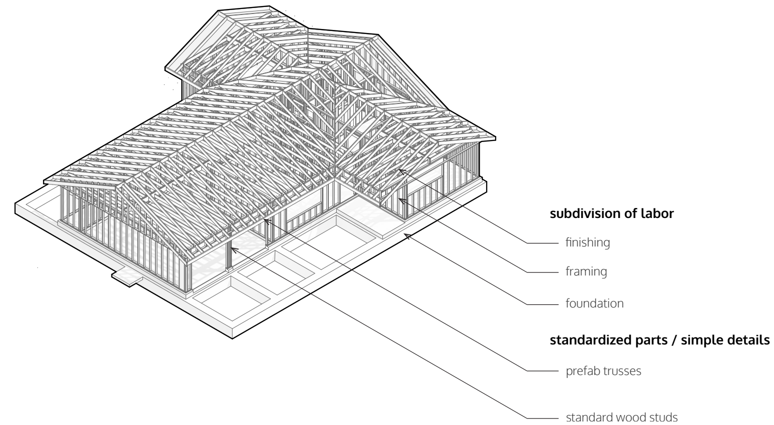
	cost per square foot of living area: material	installation	total	% of total	labor efficiency: (24′ x 38′ home) component	labor hours
site work site preparation for slab	n/a	2.19	2.19	**2.1%**	excavation	24.956
foundation continuous reinforced concrete footing with insulation, base, and vapor barrier	6.48	8.50	14.98	**14%**	concrete wall	158.688
framing exterior and interior wall frames with truss roof frame	5.49	7.76	13.25	**12.4%**	floor framing wall framing roof trusses	46.512 42.864 59.28
exterior walls exterior cladding with insulation, windows, doors, hardware, and paint	8.07	7.80	15.87	**14.9%**	vinyl siding	51.072
roofing asphalt roof shingles with building paper, gutters, downspouts, and flashing	2.27	2.74	5.01	**4.7%**	asphalt shingles	43.776
interiors walls and ceilings with gypsum board, paint, interior doors, hardware, carpeting, and flooring	11.79	13.29	25.08	**23.5%**	drywall	31.92
specialties kitchen cabinets and countertops, sinks, and water heater	3.58	1.13	4.71	**4.4%**	kitchen systems	15.486
mechanical bathroom, water closet, and hot air heating system	4.54	3.91	8.45	**7.9%**	heating / cooling	62.914
electrical wiring, receptacles, wall switches, appliance circuits, and lighting fixtures	1.20	2.09	3.29	**3.1%**	electric service	12.301
overhead contractor’s overhead and profit	6.53	7.39	13.92	**13%**		

normative single family housing

low cost / fast construction

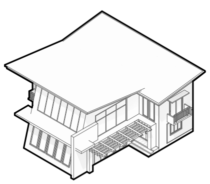


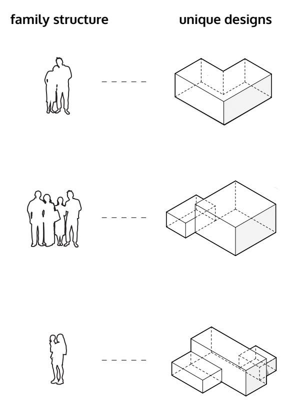


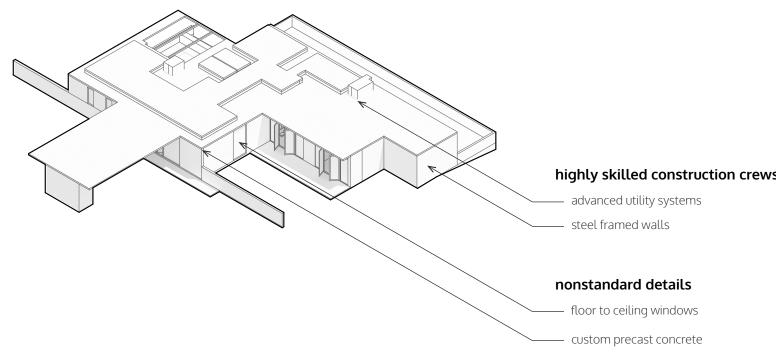


architecturally designed single family housing

high cost / slow construction



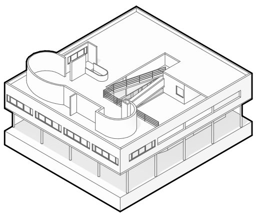




past approaches: theoretical housing

Prior to the rapid affiliation toward mass produced architecture, theoretical housing principles emerged from the growth of the International style in the late 19th century. At this time architects had a growing dissatisfaction with stylistically eclectic buildings and rapidly industrializing societies (Britannica 2018). This period also saw the emergence of the business class, who were proud of their association with a new technical age and as a result were well-suited to new ideas of functional interiors and streamlined aesthetics (Welsh 1995). These ideas dictated the search for a utilitarian homes that express a vision for contemporary life through new spatial ideas.

Despite the ambitious approach to the design of theoretical housing approaches, some argue that they force a limited social view on the occupants and fail to address sustainability and energy issues that were also products of the modern age. Additionally, many of these utopian ideas ultimately failed to provide low and middle income housing, and rather developed new models of modern living for the wealthy class instead (Welsh 1995).



villa savoye

le corbusier

home considers imagery (modern machinery) that were regarded as symbols of the modern age. however, it forces a limited social view on its occupants

cost competitiveness

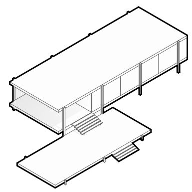
- not cost competitive

systemized for rapid construction

- construction method not systemized, but design is limited to ruleset

application to multiple images of domesticity

- mainly applies to traditional family models of the time



farnsworth house

mies van der rohe

felt the individual should exist in harmony with the culture of one's time. so he sought to display nature in its simplest and purest form

cost competitiveness

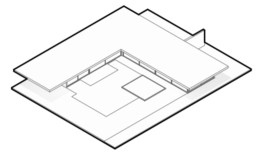
- not cost competitive

systemized for rapid construction

- construction not systemized, but utilizes repeatable design logic

application to multiple images of domesticity

- forces abnormal image of domesticity on its residents



case study houses

various

with no real clients in mind, many of the designs speculated on the possibilities of contemporary life in postwar environments. this program ultimately failed to provide low and middle income housing.

cost competitiveness

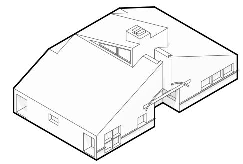
- not cost competitive

systemized for rapid construction

- construction is systemized but not applicable outside the wealthy class

application to multiple images of domesticity

- mainly applies to traditional family models of the time



venturi house

robert venturi

presented a critique of modern design, seeking to overturn the limitations and reductive simplicity of orthodox modern architecture

cost competitiveness

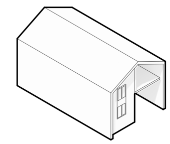
- not cost competitive

systemized for rapid construction

- construction is unique and requires very skilled labor

application to multiple images of domesticity

- mainly applies to traditional family models of the time



half - houses

elemental

made the case that housing should not be a static unit that is packaged as current normative models do. process involves residents in the building process and makes incremental growth of the units possible

cost competitiveness

- cost competitive

systemized for rapid construction

- construction method and designs are systemized

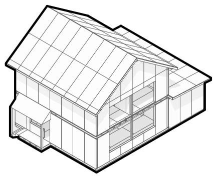
application to multiple images of domesticity

- applicable to needed / emerging models of domesticity

past approaches: prefabricated systems

Following the creation of mass produced suburban housing models, a number of architectural precedents focused on prefabrication and advanced manufacturing processes attempted to play off of the trend. The off-site manufacturing of these homes / home components in controlled factory environments affords an efficient use of skilled labor and materials. As a result, many of these systems are able to be constructed quickly, at a low cost, and produce more air-tight envelopes and energy efficiency through the precision of factory processes.

Although similar, the construction and design of prefabricated housing varies widely. Use of these prefabrication techniques in home building is still lower than normative construction practices, but the rate of growth for application is significant (CMHC 2015). Despite the results and popularity of many of these systems, the processes have rarely been adapted beyond their current use and have yet to utilize multi-objective optimization as a design tool. Lastly, the majority of prefabrication processes, while efficient, only lend themselves to one design and therefore perpetuate many of the issues that stem from normative single-family housing design.



sip panel construction

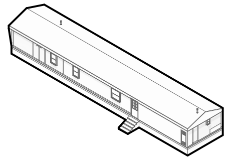
manufactures insulating foam core between sheathing for cheap construction

cost competitiveness

- cost competitive

systemized for rapid construction

- can be constructed faster than standard framing



trailer home manufacturing

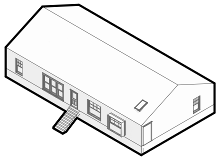
constructed quickly and at a low cost, and affords lower material waste than on-site practices

cost competitiveness

- cost competitive

systemized for rapid construction

- can be built more efficiently and to a higher quality than conventional framing



modular home manufacturing

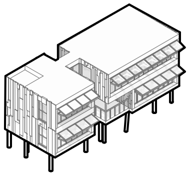
constructed quickly and at a low cost, and affords lower material waste than on-site practices

cost competitiveness

- cost competitive

systemized for rapid construction

- can be built more efficiently and to a higher quality than conventional framing



loblolly house

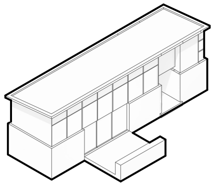
shifted 70% of construction to factory through the use of prefabricated wall panels

cost competitiveness

- not cost competitive

systemized for rapid construction

- can be built more efficiently and to a higher quality than conventional framing



flatpak house

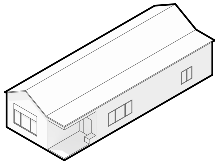
based on prefabricated 8' wall panels, allowing client to customize home, and takes just 9 days to build with a crew of 4

cost competitiveness

- not cost competitive

systemized for rapid construction

- can be built faster than conventional framing



module design group

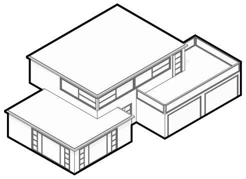
takes incremental approach to prefabrication, allows set additions to home as needed

cost competitiveness

- not cost competitive

systemized for rapid construction

- prefabricated construction allows for more efficiency than standard framing



bone structure construction

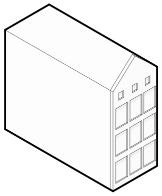
steel manufacturing structure that can be modified to fit various designs and is energy efficienit through its tight envelope

cost competitiveness

- not cost competitive

systemized for rapid construction

- construction method systemized but takes longer than conventional framing



3d printed canal house

implements emerging 3d printing technology to home construction allowing recyclability and smart consumption

cost competitiveness

- not cost competitive

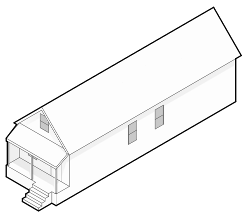
systemized for rapid construction

- construction method systemized but takes longer than conventional framing

past approaches: cnc driven residential design

Following the development of computer numerically controlled milling machines, a number of precedents hoping to harness its speed and precision as a means to implement inexpensive prefabrication into residential design began to develop. The continued growth of Computer Numerically Controlled (CNC) systems has created construction strategies that result in air tight building envelopes and a reduced need of skilled labor due to its precision cutting capabilities.

While utilizing these processes removes the time consuming measuring and cutting of pieces at construction sites (Lloyd 2018), great demand of mental resources and time is still required to manually generate the thousands of component geometries for the construction models involved, and as the homes increase in size so will the complexity of their assembly, in which there is little to no skilled labor (MIT 2018). Additionally, greater development in the structural capabilities of plywood structures is needed if the system is to be applied to larger structures or to be able to reach the increased spans expected of normative residential models.Until these developments are made, CNC systems will continue to depend upon the kit of parts or small modular pieces that are inherent in previously mentioned strategies.



instant house

larry sass

avoided large scale equipment, power tools, and nails from the job site. utilizes notched plywood cut from a CNC machine. removed time consuming measuring and cutting processes from construction sites

construction speed

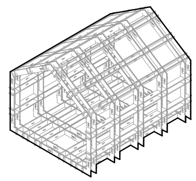
- takes longer to construct than normative processes

fits variety of family structures

- fits the typical nuclear family structure

universal parts

- utilizes unique pieces for each design



wikihouse

based upon assembly of cnc cut plywood without the use of nails or screws. enables users to create designs and implement them into wikihouse software, which generates cnc cut files

construction speed

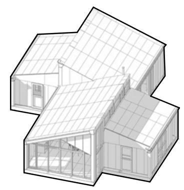
- can be constructed faster than normative processes

fits variety of family structures

- fits emerging family structures

universal parts

- utilizes unique pieces for each design



facit homes

constructs homes from modular plywood elements rather than unique pieces fundamental in other approaches

construction speed

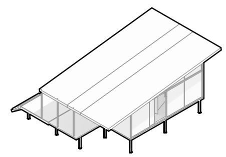
- takes longer to construct than normative processes

fits variety of family structures

- fits the typical nuclear family structure

universal parts

- utlizes universal modular plywood construction



clt housing

large scale prefabrication of solid, layered timber walls. low environmental impact and great design customization

construction speed

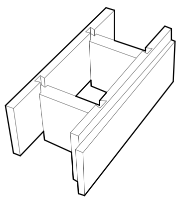
- able to be constructed in less time than normative methods

fits variety of family structures

- able to fit a variety of emerging family structures

universal parts

- utilizes unique pieces for each design



brikawood systems

construction of 'wood bricks' that allows for rapid construction without the use of nails, screws, or adhesives minimizes need to cut many different sized component parts as found in previous approaches

construction speed

- takes longer to construct than normative processes

fits variety of family structures

- able to fit a variety of emerging family structures

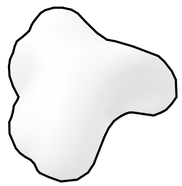
universal parts

- utilizes universal parts for each design

past approaches: generative design in residential architecture

In order to avoid adding further boundaries to residential construction efficiencies as some previous examples have done, a number of precedents utilize optimization and performance analysis as a tool to inform architectural design. The development of generative approaches in architecture presents numerous possibilities to the field of architecture in terms of both efficiency and performance. For example, research shows that procedural generative architecture can be derived from numerous data sources, many of which can provide tangible benefits to suburban home design through the manipulation of form to benefit things such as energy use or construction waste.

The landmark projects in this area, however, have been conceptual and speculative in nature and lack the constraints needed to be incorporated into normative construction processes. Many of the works would have benefitted from the optimization of objective measures related to both building performance and the limitations of its structural members. This is because automated manufacturing technologies for the production of non-standard forms are not nearly as robust as those being utilized for the standard “kit of parts” approach of current residential typologies. With the incorporation of these measures, the output models would lend themselves to typical construction processes and be a realistic alternative to contemporary residential design practices.



embryological house

greg lynn

saw the house as an interactive system through which a user could invent their own space through software. this program informs the space by considering several adaptations to lifestyle including site, climate, construction methods, materials, functional needs, and aesthetic effects

constructability

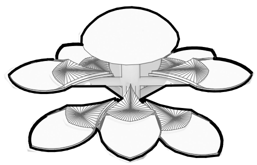
- can't be constructed with normative methods

fits variety of family structures

- can be adapted to unique family structures

optimization applies to different contexts

- optimization fits multiple contexts



digital botanic architecture

dennis dollens

generative approach that derives its form from nature by utilizing animation software that considers botany and aesthetics

constructability

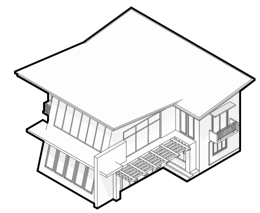
- can't be constructed with normative methods

fits variety of family structures

- cannot be adapted to unique family structures

optimization applies to different contexts

- optimization fits multiple contexts



bim-based energy performance multi-objective optimization

mohammad rahmani

develops an alternative workflow to residential design that looks to implement performance based optimization into early stages of design. allows designers without parametric modeling experience to implement energy sufficient design optimization strategies

constructability

- utilizes standard construction practices

fits variety of family structures

- has yet to be adapted to unique family structures

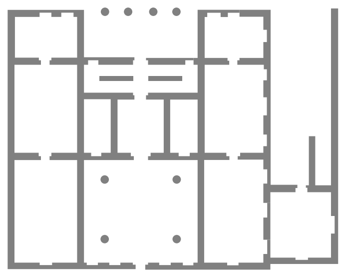
optimization applies to different contexts

- optimization fits multiple contexts

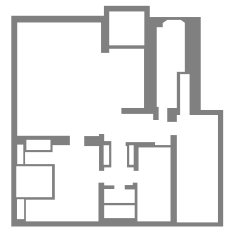
where past approaches fail:

The question then becomes, why have all of these approaches failed to affect suburban design? Despite their consideration toward fabrication and mass production, the vast majority of them fail to embed themselves within existing standards of the typology, and don't look to benefit all of the existing players of residential development. An example of this can be found in the work of Robin Evans, who contrasts the layouts of the 16th century Italian Renaissance model of interconnected rooms and the corridor-based arrangement of England in the 19th century, citing the societal shifts of privacy as the means to change the overall design of the typology. As this relates to suburban typologies, we can see that the introduction of the automobile required suburban designs to adapt and incorporate attached garages to the homes. This subtle change in the design typology of single family homes shows that large societal shifts are required to break through some of these existing standards as they've become the expected standard for suburban design.

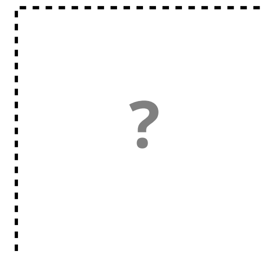
There are a number emerging societal shifts as well as various barriers in the development of single family homes to consider for an alternate suburban model. First, developers face extensive permitting processes for the creation of suburban homes, and typologies or fabrication strategies outside of the norm tend to extend this process. This same idea also applies to construction processes, which are commonly zoned out of city ordinances and as a result often face difficulty funding, a lack of municipal experience, etc. Lastly, financial lenders to suburban developments are primarily concerned with their bottom line, or how much and how easily they could sell the assets for in case of a fire sale or emergency. This tendency justifies their potential hesitance to alternate delivery models or unique design aesthetics in housing developments, which are considered to pose greater financial risk. With all of these various factors considered, it demonstrates the importance of alternate suburban models embedding themselves within existing standards of the typology and seeking to incorporate incremental improvements in the workflow that benefit all players involved.

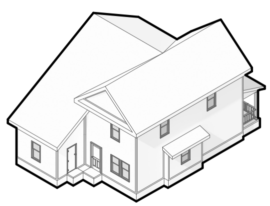


interconnected rooms scheme
palazzo antonini udine / andrea palladio

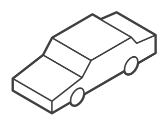


passage driven scheme
the functional house / alexander klein

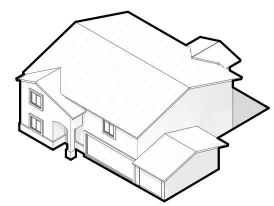




standard single family home design



widespread use of cars

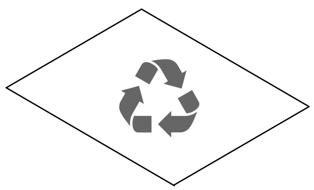


standard single family homes designed to include accessary garage

normative housing development process

step 1

federal and local permits



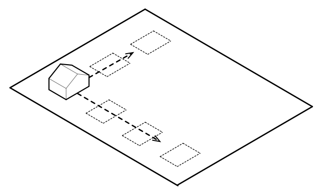
1.01 federal environmental review

1.02 environmental impact statement

1.1 federal permits

step 2

concept / design approvals



2.01 rezoning, variance, and special exception

2.02 concept submittal

2.1 planning and zoning commission hearings

2.11 subdivision plan

2.12 staff review

2.13 submit preliminary subdivision plan

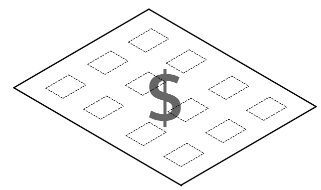
2.2 planning commission hearings

2.21 submit final subdivision plan

2.3 planning commission approval

step 3

permit acquisition and fees



3.01 post construction bonds

3.02 pay impact and other fees

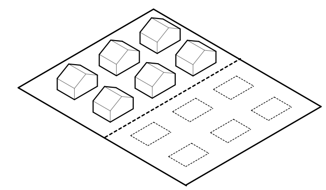
3.03 obtain grading and other permits

3.04 obtain building permits

3.1 prepare for construction / lot sale

step 4

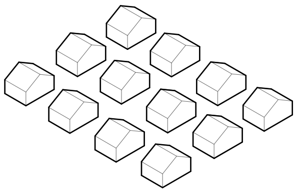
sale of land / homes



4.01 sell lots or build homes

4.1 sell / lease homes

normative development and ownership techniques



typical subdivision development model

-single use

-single housing type

-minimum lot size

-strict setbacks

-all land planned for private use

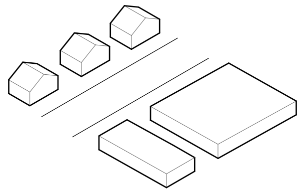
+ predictable results and relatively easy to administer

+ easy for developers to obtain approval

- limited housing choices and open space

- emphasis on cars rather than people and promotes sprawl

- poor connectivity and segregation of uses



planned unit development (pud)

-mixed use

-mix of housing types

-flexibility in lot size and setbacks

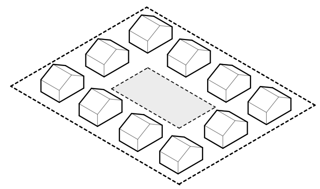
-typically includes common areas (15 - 20%)

+ allows homeowners convenient access to shops and other commercial buildings

+ common areas are able to be maintained by outside community

- tend to be more expensive for the average homeowner

- generally involves more guidelines to follow on aesthetics and community standards



cluster or conservative subdivision

-single use

-usually single housing type

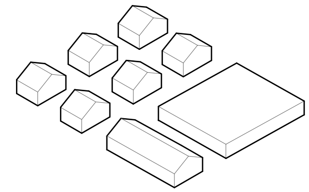
-flexibility in lot size and setbacks

-emphasis on open space and natural area preservation

+ more green / public space as well as closer community

+ optimal stormwater management practices

- cluster developments often encounter planning objections



traditional neighborhood development

-mix of uses including neighborhood center with civic uses

-mix of housing types

-emphasis on walkability and human scale

-street connectivity

-architectural quality

-higher density

-form based zoning

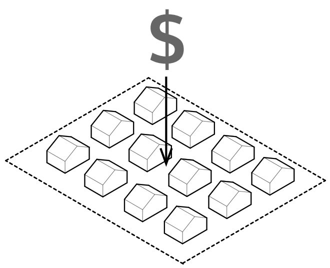
+ compact and pedestrian oriented development with a mix of commercial and residential uses

+ allows a variety of housing types and public places where people have opportunities to socialize

- tends to be associated with a higher price of home

- homes tend to have less privacy since pedestrian circulation is given priority

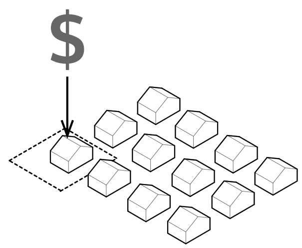
lender considerations



fire sale price of the security

financially, a fire sale refers to any sale where the seller is under financial distress

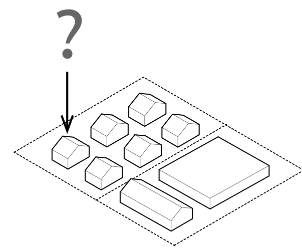
in terms of housing, it refers to a worst case scenario. Or if the banks took ownership of your assets, what is the maximum amount of money that they could sell them for



the end value of the dwellings

the banks will determine what the value of the homes / assets could be, and use this to determine whether or not they will be able to easily sell them in a worst case scenario.

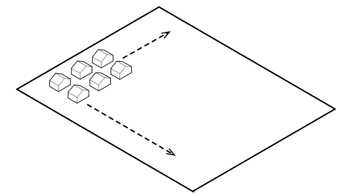
if they are higher than the median price in your area they see these as lower quality security as they may be more difficult to sell.



the zoning of the security

depending upon the site location of development, the determined zoning of the location by local municipalities will play a role in potential property values.

residentially zoned land is the most highly regarded as it is the easiest to sell. rural properties would be seen as less secure and hence the banks will lend a lower proportion on these.



location and usage of the security

the location and usage of a security plays a big role in whether or not funding will be provided as banks look at developing trends in these areas to determine the potential risk involved.

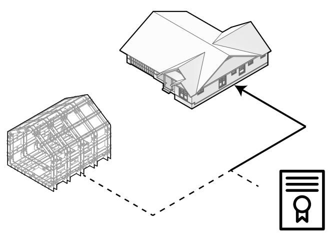
lenders prefer to lend against properties in areas that have a long history of strong capital growth and in large population centres. banks also prefer to lend against the security of residential real estate compared to more unique styles of development asthey pose more risk financially.

financial barriers

permitting

obtaining permits for manufactured and modular homes might be more time-consuming than securing permits for site-built homes

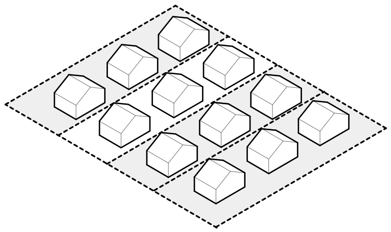
local authorities may be unfamiliar with these building technologies. This will vary from city to city.



zoning

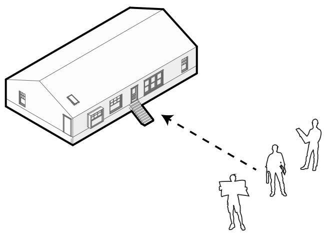
in some cities manufactured homes are, in fact, zoned out. this is changing but can present a big hurdle if this is the case.

officials may perceive a manufactured home to be nothing more than a trailer and, as such, not up to standards. in 1998, a study showed that only 29 percent of communities had regulations that treated site - built homes equally to manufactured homes



experience of local municipality

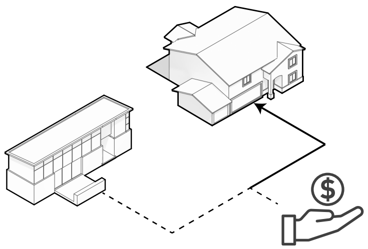
chances are city building officials will have little, if any, experience with manufactured and modular homes and this can translate into significant delays in moving a project through the approval processes.



financial funding

for community development corporations and other nonprofit groups using manufactured or modular housing, there should be little impact on financing programs.

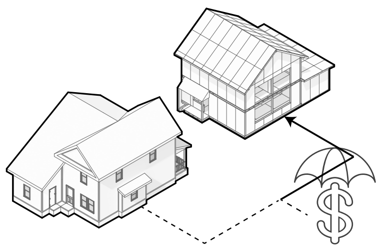
there is one vital caveat here: without favorable appraisals, financing may be severely affected. appraisers must be educated about modular and especially manufactured homes. some developers report resistance from appraisers when it comes to using modular or manufactured homes.



insurance

general contractors and subcontractors who have not worked with manufactured or modular homes should be able to safely continue with the general builder liability insurance they use and should not have to reconsider any insurance issues.

though rates for factory-built homes were once 20 percent higher than rates for site-built homes, they are now much more comparable. there is an opportunity to reduce insurance cost by placing less risk in the construction of the home.



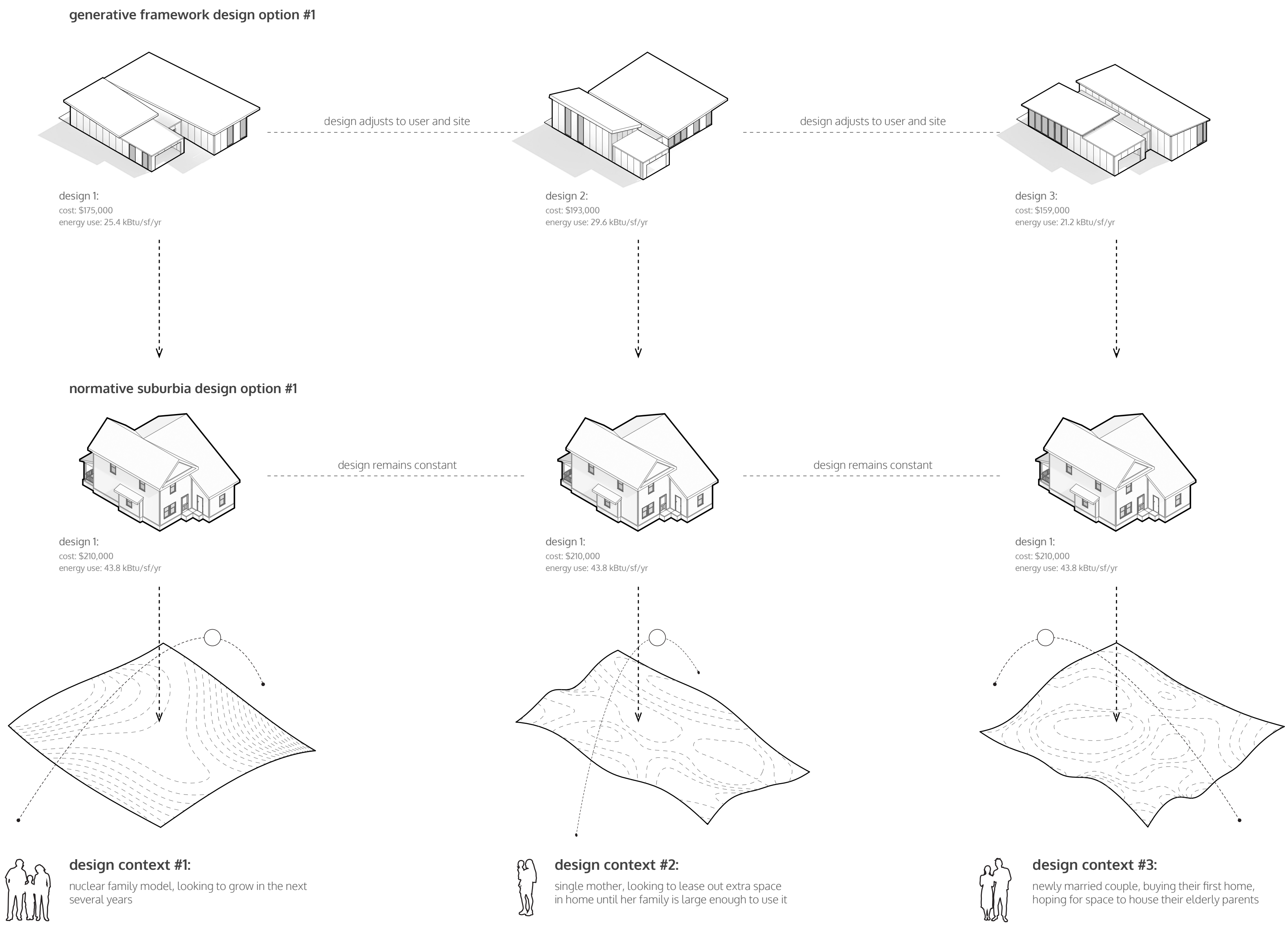
04 / methodology

The generative framework developed through this thesis utilizes numerous data points related to the different architectural elements of the home (e.g., location and orientation of the home, program sizes, room height, pitch, etc.) as well as the dimensional characteristics of its construction as the decision parameters within a multi-objective optimization process. The multi-objective optimization algorithm developed assigns values to these parameters that respond to various desired objectives related to the home's contextual setting, user profile, and other unique circumstances in order to work toward optimal models. Critics of this performance-based optimization approach cite the lack of aesthetic consideration as well as missing the judgement and intuition common in human approaches (Marble 2012). To address this, the DPA-NSGA-II (dynamic progressive for architecture – nondominated sorting genetic algorithm II) is utilized as the optimization engine. This engine allows designers to continue to design and discover new objectives during the optimization process (Newton 2018). DPA-NSGA-II allows the architect to influence the direction of the optimization by ranking the variations within each generation's pareto front based on how they align with desired qualitative goals. The optimization engine then bases future outputs off of that selection, thereby narrowing the search for models by not considering solutions that fail to align to the qualitative objective. This is the approach to the previously mentioned 'many objective problems'. The adjusting of data parameter values through this intuitive optimization workflow therefore theoretically requires a human component to adequately mimic typical design processes, further integrating architects into the design of single-family housing. Once the optimization of the framework has been completed, optimal models can be selected, with the framework automatically generating the various structural components involved. This process affords suburban typologies with the design sensibilities of high-end residential architecture with the speed and cost of low-end solutions that have removed contextual design considerations.

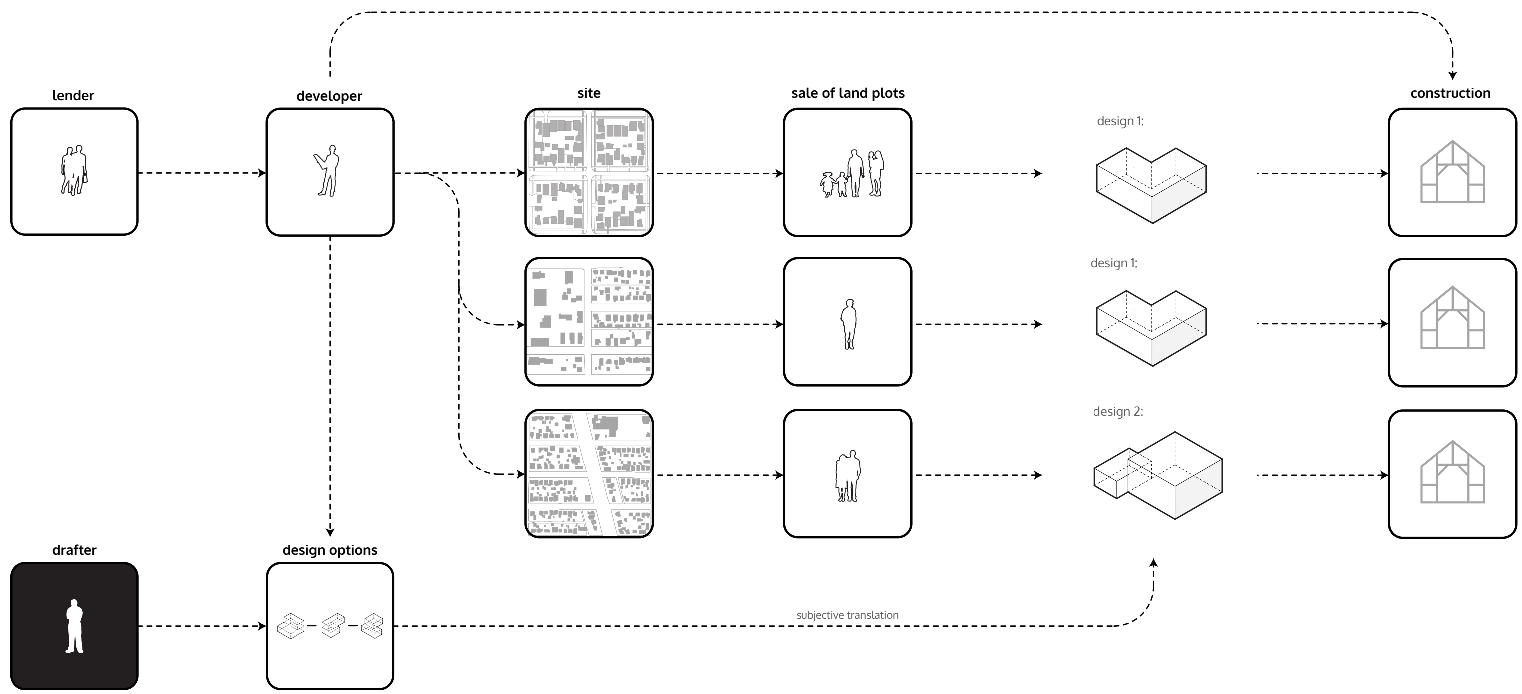
In addition to the development of the generative framework, this thesis outlines the role of this workflow within normative single-family housing design processes, from pre-design through the construction of the home. In the actual development of generative framework homes, a digital design library features various aesthetic languages for a client to select from. Upon selecting a formal aesthetic language, a general massing is displayed along with changing variables and possible objectives for the architect to optimize for. In general, the flow of program remains consistent with the layout featured on this page, however other factors such as glazing percentages, area dimensions, roof pitches, etc. will change through the development of the optimization based upon the desired objectives to optimize for. If the client chooses to select an aesthetic language or design option, they then enter basic parameters for that framework, which includes site information, family information, and desired program. Additionally, a number of these parameters have the option to leave them to the architect's discretion if the client doesn't have specific values readily available. After the client provides these inputs, the role of developing the framework then shifts to the architect to provide the remaining inputs or even edit the framework to match the client's program or budget. Similarly to the client parameters, the architect can select for the inputs to change with the optimization if they do not require specific values. The architect then runs the optimization of the framework to produce a number of design options that are closely related to the client's needs. If the client approves a recommended design option, the framework then outputs structural components as well as construction drawings, allowing the project to carry through the construction phase in a standard fashion. This digital interface is also able to serve as a manual that allows for the architect to understand the design logic of the framework, so that if design changes to the framework are required, they are readily prepared to make those adjustments.

The incorporation of the generative framework within suburban design processes limits the time commitment of the architect's non-computational involvement as well. Instead of using this workflow as his or her primary portfolio, it is recommended that the architect can complete these home commissions between the firm's major projects. A large number of these types of projects, including renovations, facility assessments, and accessibility improvements, make up large shares of many firm's work, and the development of suburban homes through this streamlined workflow would help to supplement this portion of the firm's portfolio. In general, the phases which require a greater time commitment can be compensated at a higher rate in order to ensure the non-computational architectural processes are competitive with existing time standards.

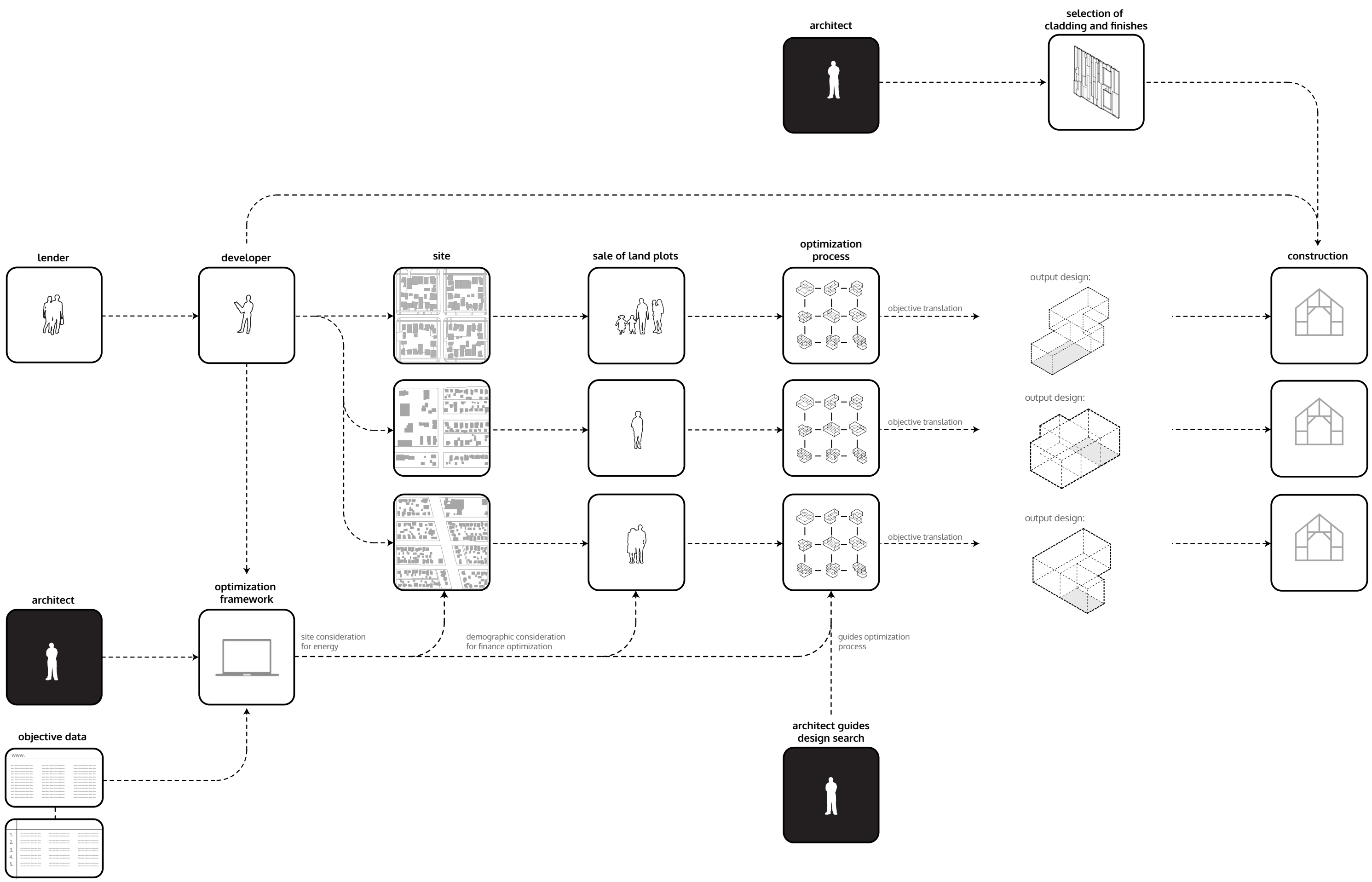
In order to determine the success of the algorithm, present residential conditions will be analyzed for the various optimization objectives available to ensure the optimized design outperforms current housing solutions. To test the outputs, current housing models will be subjected to building performance simulations through the use of Ladybug Honeybee, an environmental analysis plug-in for Rhino. This will allow for the testing and optimization of numerous quantitative performances including useful daylighting, ventilation performance, utility cost, and view analysis. Some desired quantitative housing aspects lack appropriate measuring software and will require the creation of grasshopper definitions in order to measure them. These include cost analysis of the home and attached leasing spaces for unique typologies, construction waste, etc. Additionally, several qualitative performances are required for the adequate design of single family homes, and are determined through the use of the DPA-NSGA-II optimization engine. These include the number and size of various programs, optimal location of the home on the site, program adjacencies, etc. Optimized design models will be output from separate client profiles in Lincoln, Nebraska and Phoenix, Arizona and tested under the same simulation in order to both display the variability of the algorithmic system in unique circumstances as well as afford comparison to normative designs.

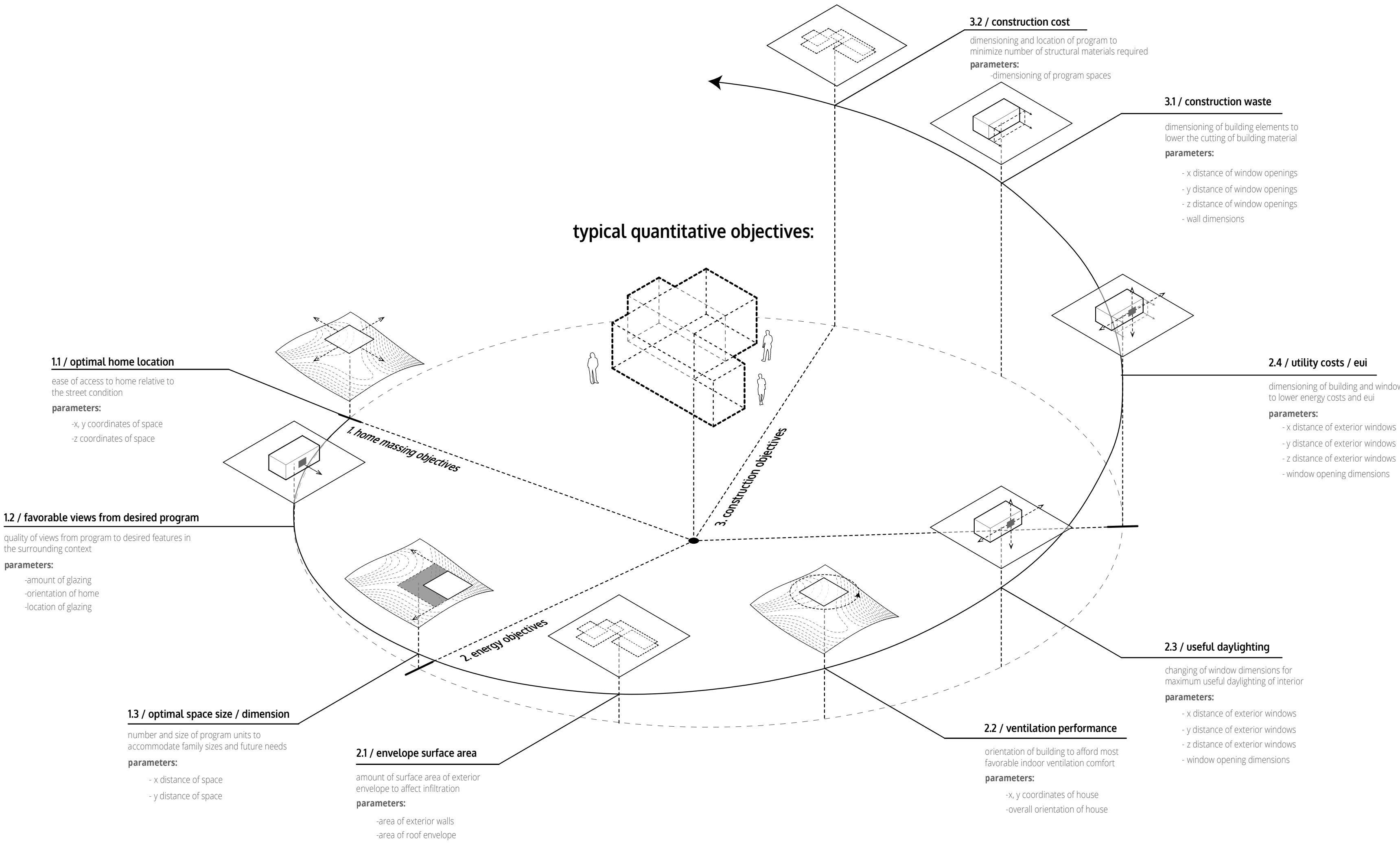

generative framework design option #1
design adjusts to user and site
design adjusts to user and site
design 1:
cost: $175,000
energy use: 25.4 kBtu/sf/yr
design 2:
cost: $193,000
energy use: 29.6 kBtu/sf/yr
design 3:
cost: $159,000
energy use: 21.2 kBtu/sf/yr
normative suburbia design option #1
design remains constant
design remains constant
design 1:
cost: $210,000
energy use: 43.8 kBtu/sf/yr
design 1:
cost: $210,000
energy use: 43.8 kBtu/sf/yr
design 1:
cost: $210,000
energy use: 43.8 kBtu/sf/yr
design context #1:
nuclear family model, looking to grow in the next several years
design context #2:
single mother, looking to lease out extra space in home until her family is large enough to use it
design context #3:
newly married couple, buying their first home, hoping for space to house their elderly parents

normative suburban design process

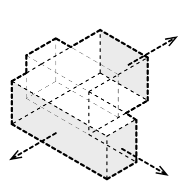


generative suburban design process





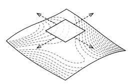
typical quantitative objectives:
3.2 / construction cost
dimensioning and location of program to minimize number of structural materials required
parameters:
-dimensioning of program spaces
3.1 / construction waste
dimensioning of building elements to lower the cutting of building material
parameters:
- x distance of window openings
- y distance of window openings
- z distance of window openings
- wall dimensions
1.1 / optimal home location
ease of access to home relative to the street condition
parameters:
-x, y coordinates of space
-z coordinates of space
1. home massing objectives
3. construction objectives
2.4 / utility costs / eui
dimensioning of building and windows to lower energy costs and eui
parameters:
- x distance of exterior windows
- y distance of exterior windows
- z distance of exterior windows
- window opening dimensions
1.2 / favorable views from desired program
quality of views from program to desired features in the surrounding context
parameters:
-amount of glazing
-orientation of home
-location of glazing
2. energy objectives
2.3 / useful daylighting
changing of window dimensions for maximum useful daylighting of interior
parameters:
- x distance of exterior windows
- y distance of exterior windows
- z distance of exterior windows
- window opening dimensions
1.3 / optimal space size / dimension
number and size of program units to accommodate family sizes and future needs
parameters:
- x distance of space
- y distance of space
2.1 / envelope surface area
amount of surface area of exterior envelope to affect infiltration
parameters:
-area of exterior walls
-area of roof envelope
2.2 / ventilation performance
orientation of building to afford most favorable indoor ventilation comfort
parameters:
-x, y coordinates of house
-overall orientation of house



1. relation of design to context

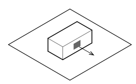
normalized objective: massing / programming to user need

subobjectives:



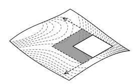
optimal location of the home on the site

qualitative
measuring tool:
architect



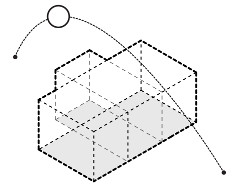
highest quality of views from desired spaces

quantitative
measuring tool:
ladybug



number and size of programs to match future family needs

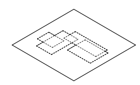
qualitative
measuring tool:
architect



2. energy performance evaluation

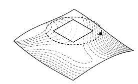
normalized objective: minimize heating and cooling energy use

subobjectives:



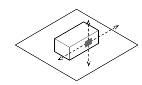
lowest surface area of exterior envelope

quantitative
measuring tool:
custom surface area calculator



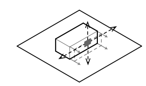
optimal ventilation performance

quantitative
measuring tool:
honeybee



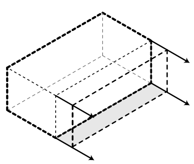
optimal useful daylighting

quantitative
measuring tool:
ladybug



lowest utility costs and eui

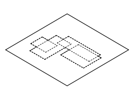
quantitative
measuring tool:
ladybug



3. construction evaluation

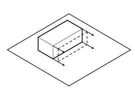
normalized objective: minimize construction waste and cost

subobjectives:



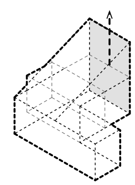
minimizing of construction cost

quantitative
measuring tool:
custom grasshopper definition



reduction in construction waste

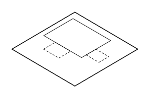
quantitative
measuring tool:
custom grasshopper definition



4. organization and spatial quality

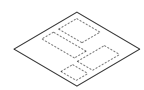
normalized objective: optimize quality of interior and exterior spaces

subobjectives:



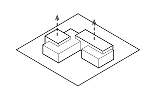
appropriate location and size of landscape and patios

qualitative
measuring tool:
architect



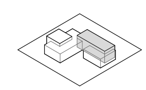
program adjacencies and flow of circulation

qualitative
measuring tool:
architect



readability of building massing

qualitative
measuring tool:
architect



quality of lighting condition

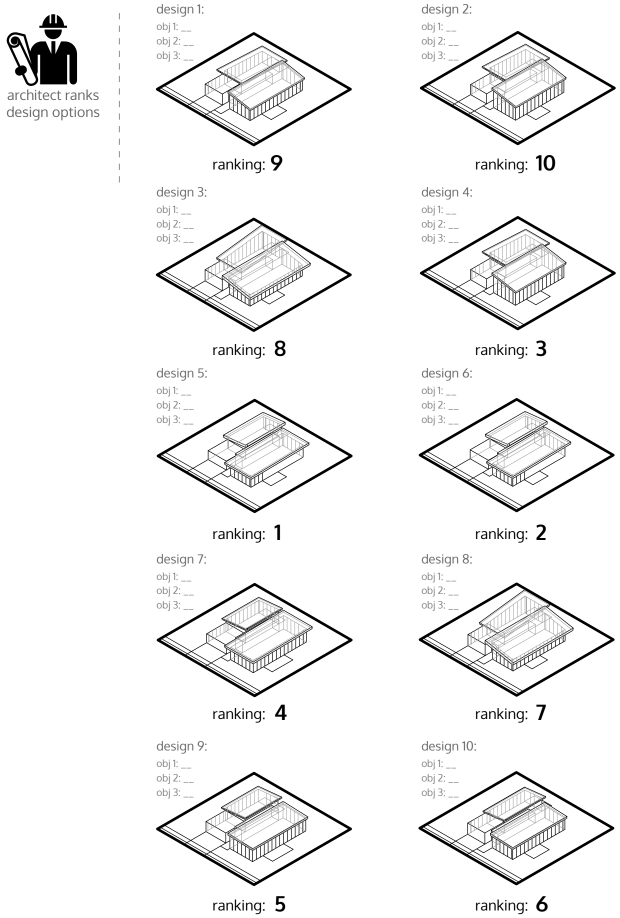
qualitative
measuring tool:
architect

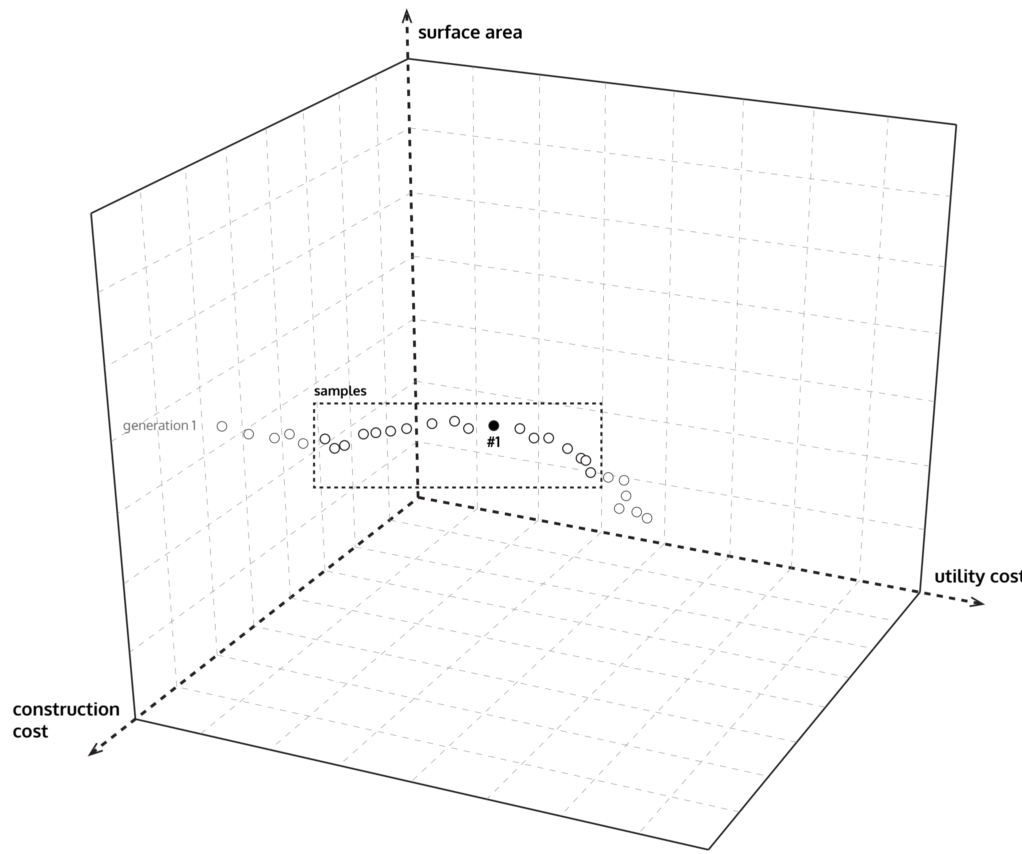
architect directs optimization through determination of qualitative objectives:

multi - objective optimization example #1:

1st generation population ranking

qualitative objective: quality of light in living space



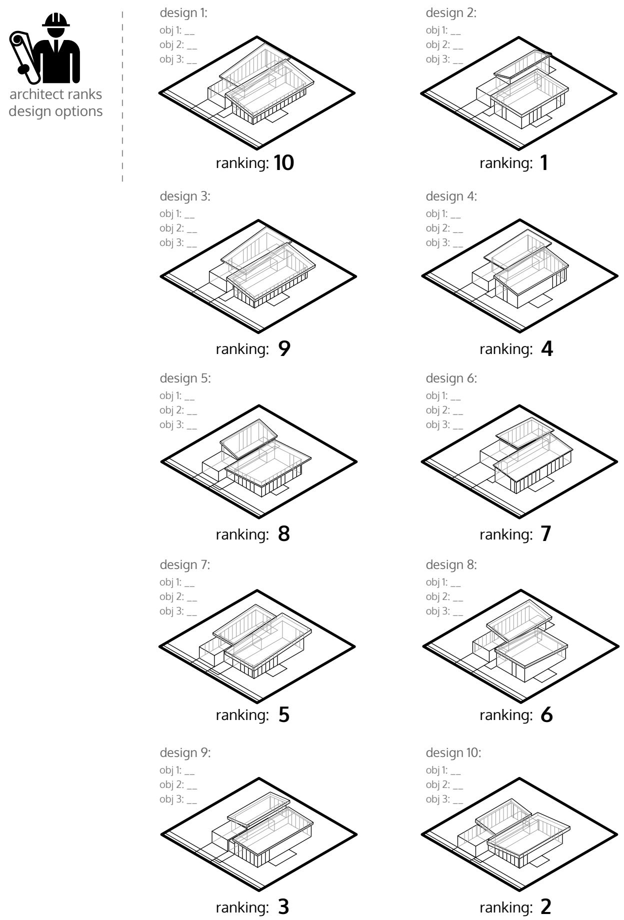


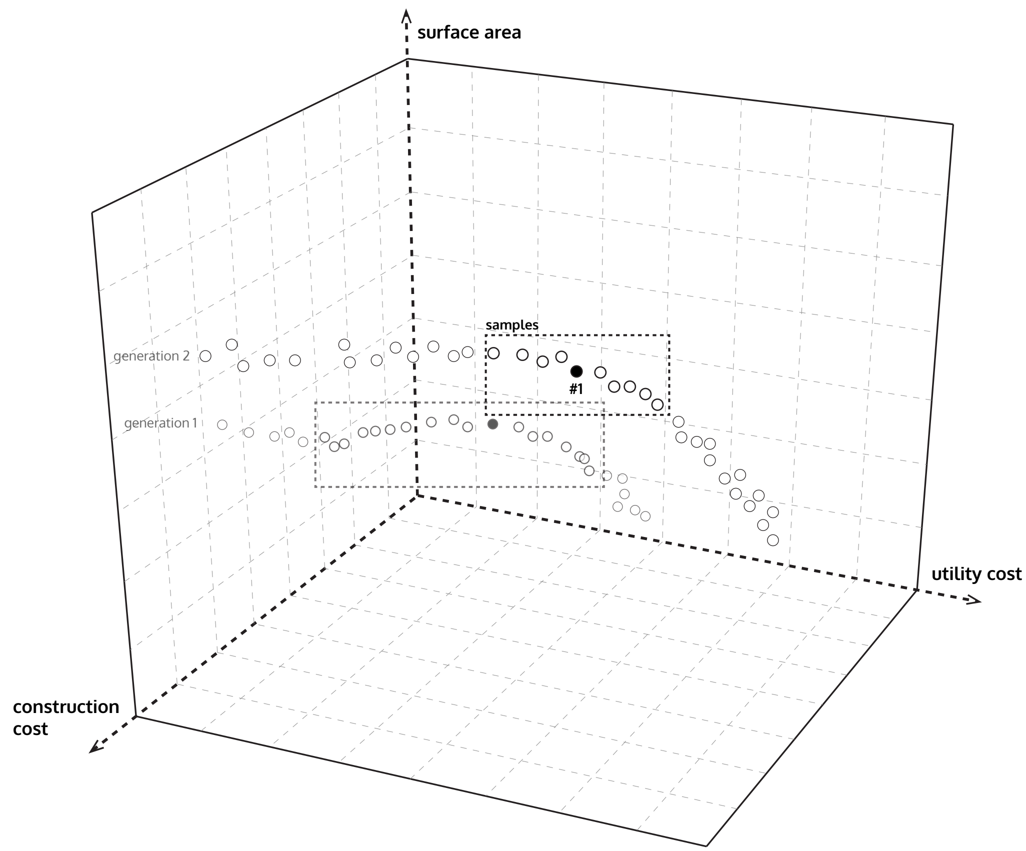
architect directs optimization through determination of qualitative objectives:

multi - objective optimization example #1:

2nd generation population ranking

qualitative objective: quality of light in living space



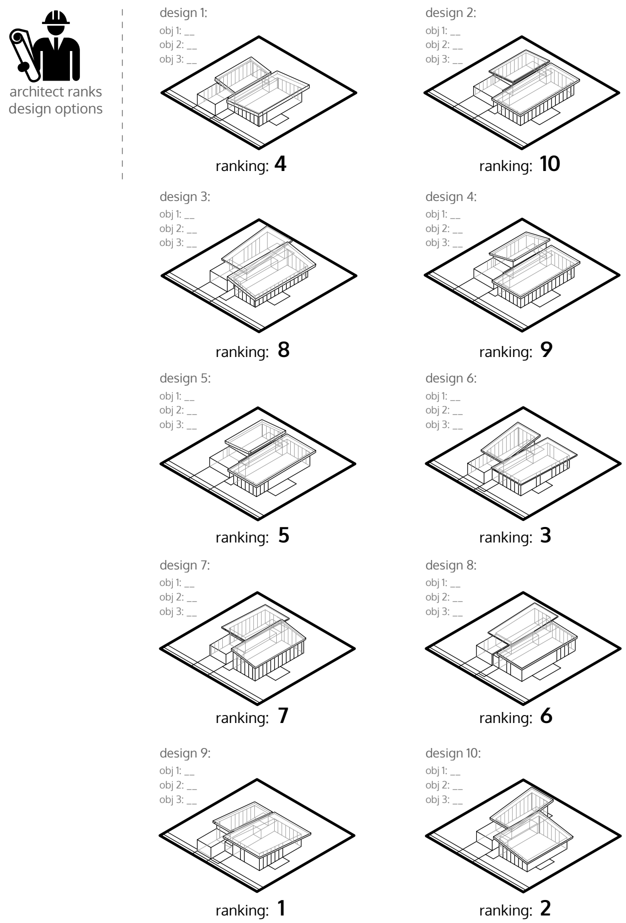


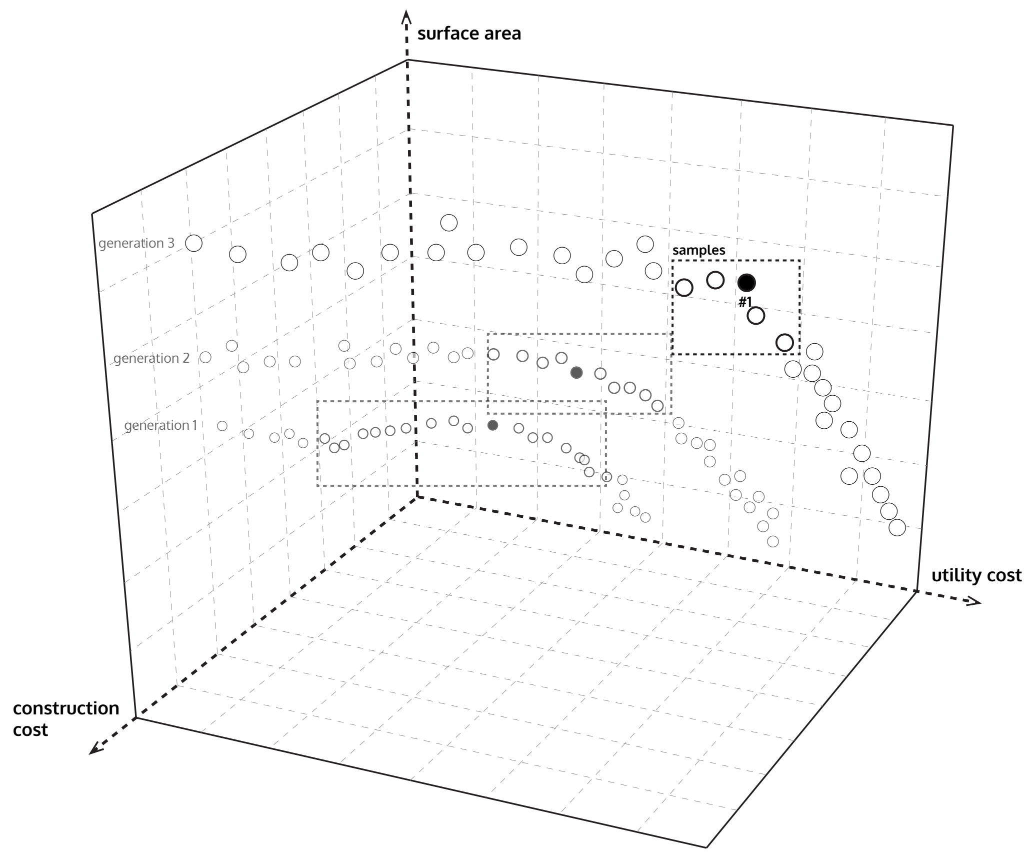
architect directs optimization through determination of qualitative objectives:

multi - objective optimization example #1:

3rd generation population ranking

qualitative objective: quality of light in living space

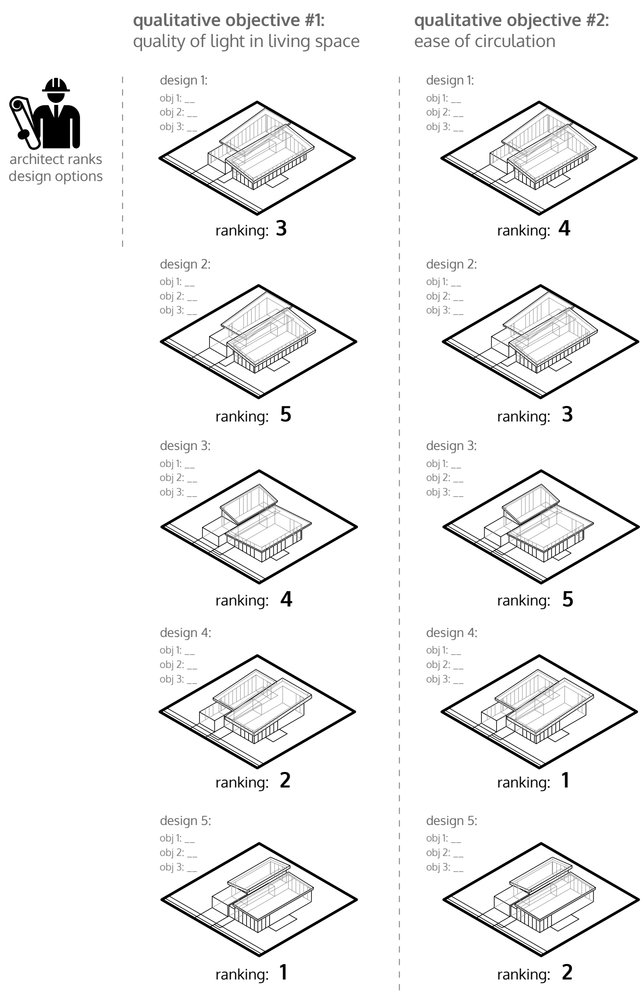


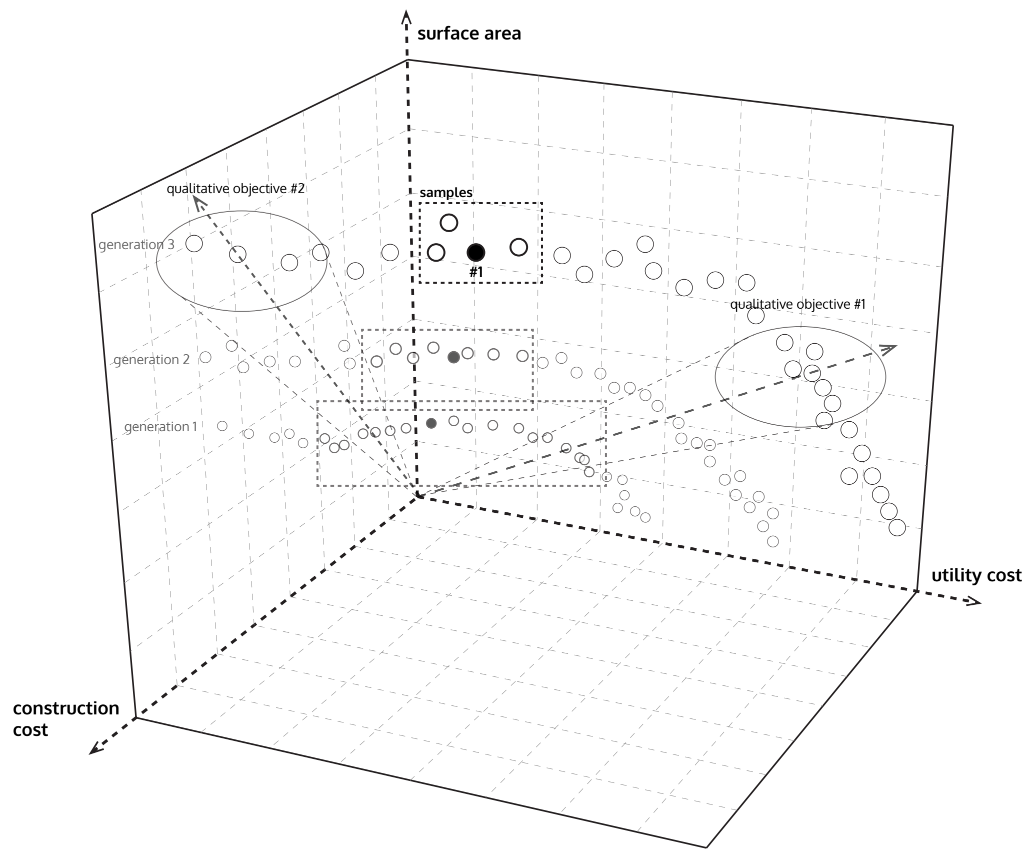


architect directs optimization through determination of qualitative objectives:

multi - objective optimization example #2:

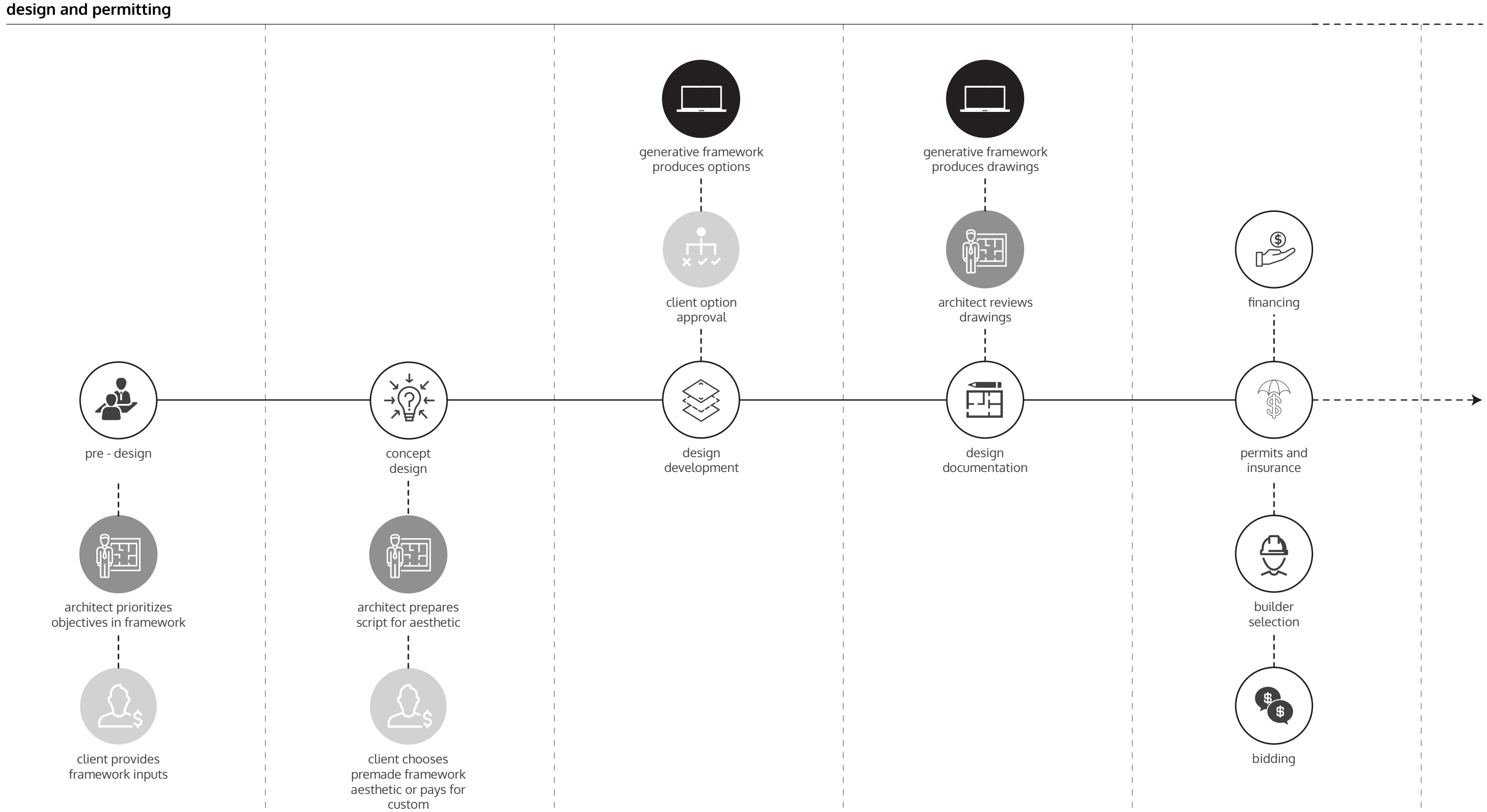
3rd generation population ranking





generative framework role in housing process:

design and permitting



pre - design specifics:

client provides:
- information to establish program and budget
- access to site information
- provide architect with inputs for generative framework

architect provides:
- generative framework in which to input values provided by client
- edits framework to match client program and budget

concept design specifics:

client provides:
- chooses from architect's predesigned aesthetic generative frameworks
- Or, provides an alternate aesthetic in which they pay they architect to incorporate into the framework

architect provides:
- guides search process and selects options for the client to choose from
- incorporates alternate aesthetic into generative framework if the client desires

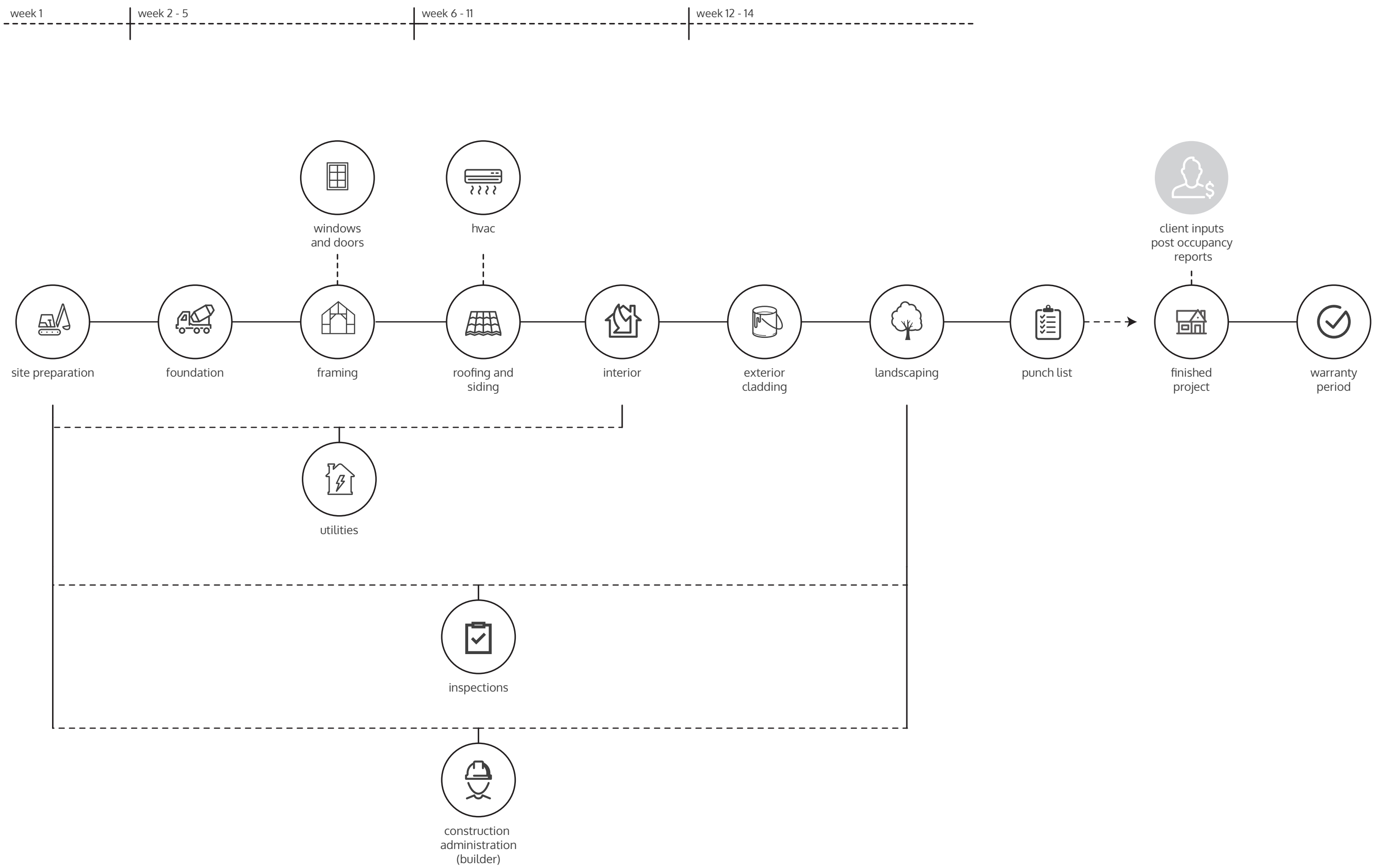
design development specifics:

client provides:
- alternate direction if output models do not satsify aesthetic tastes
- approval to proceed to construction documentation of desired model

architect provides:
- design outputs from generative framework related to client need
- incorporate feedback into framework if output models do not satisfy aesthetic tastes

generative framework role in housing process:

construction

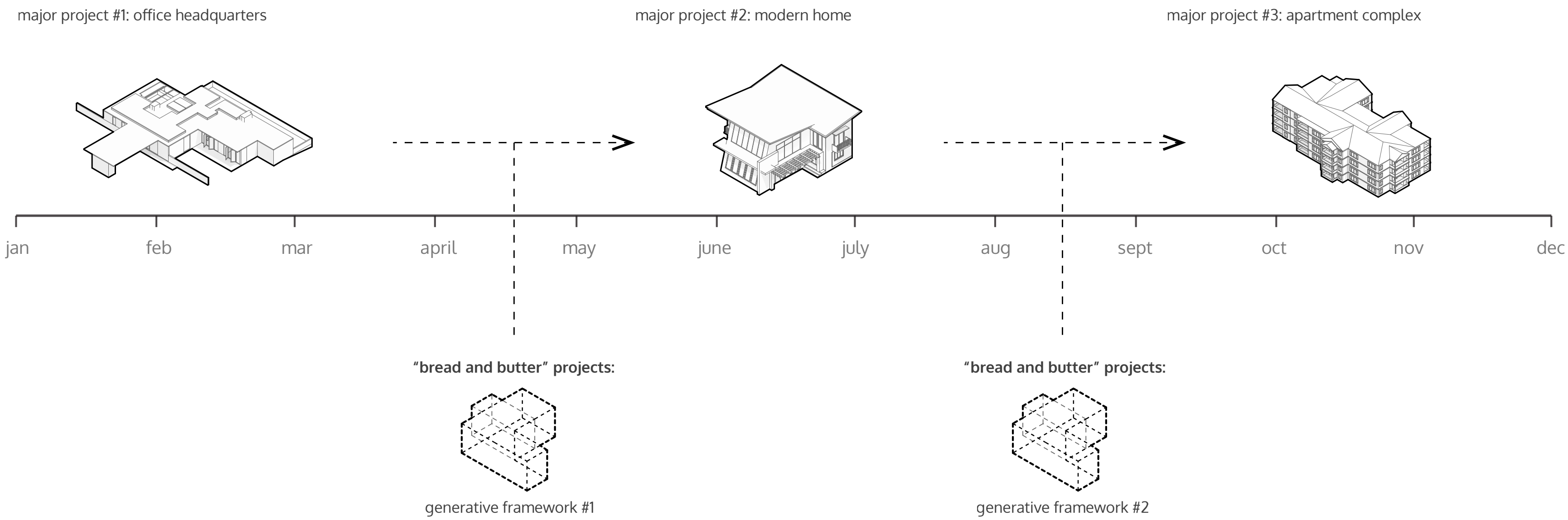


generative framework example implementation:

major project: significant projects such as public libraries, modern homes, offices, etc. that tend to have large budgets and make up the bulk of the firm's portfolio.

bread and butter project: minor renovations, facility assessments, accessibility improvements or other projects that are less prominent but actually comprise a large share of work and annual billings. These projects help fill the gap between major project commissions and economic downturns.

hypothetical firm workload:

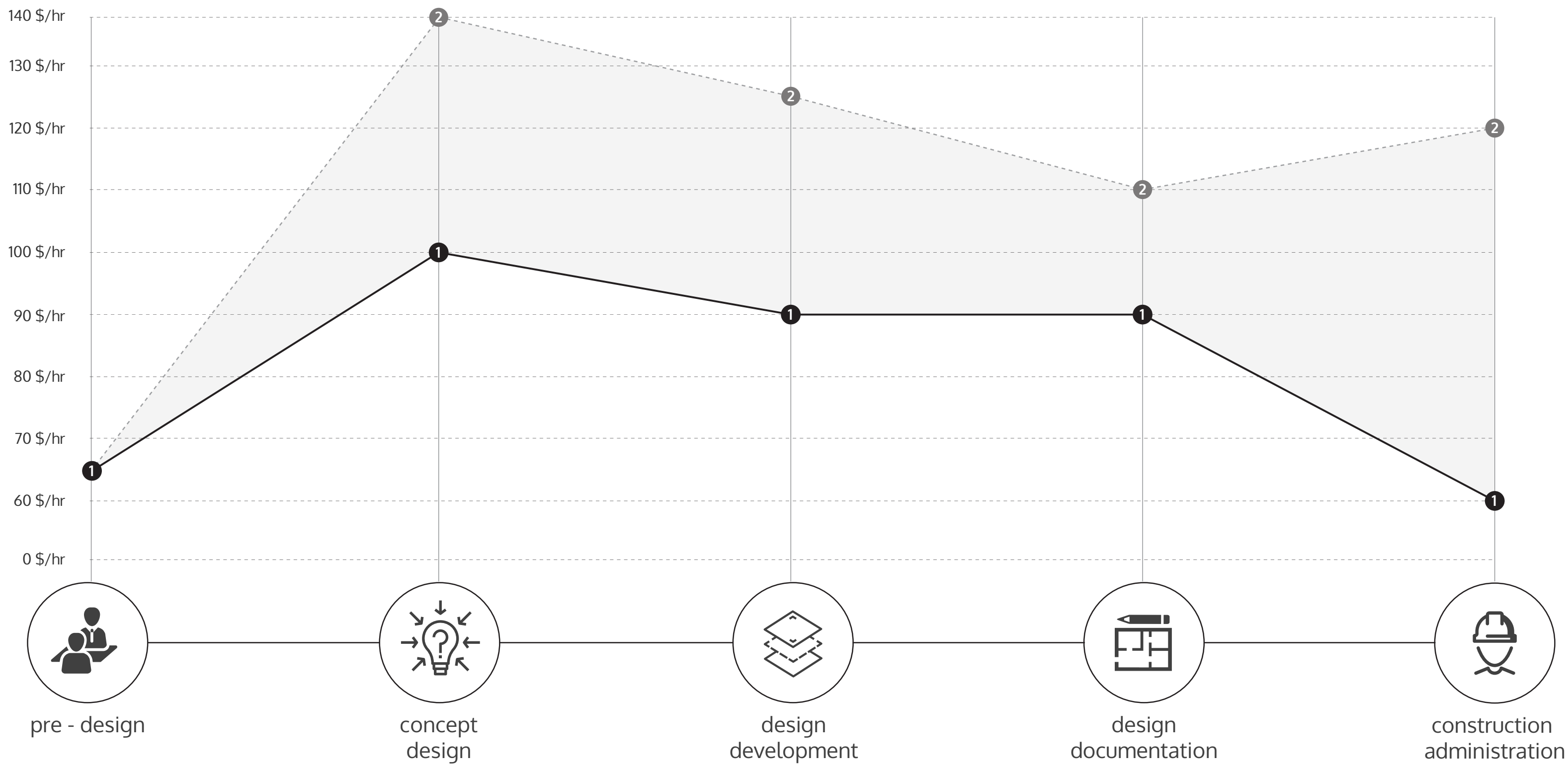


the use of a generative script simplifies home design to allow prominent architecture firms to design suburban homes efficiently as "bread and butter" type projects

generative framework example pay model:

the architect's hourly rate / fee within the generative suburban framework is paid in installments based on the phases of the project, and can be adjusted with each phase depending on the difficulty of the work involved

the following is a suggested fee schedule to ensure projects that demand time commitments are compensated accordingly, actual fee schedules will vary between different firms



pre - design

1. edits framework to match client program and budget

1.2 inputs values provided by client into generative framework

1.3 determines priority / weight of optimization objectives

concept design

1. presents aesthetic options for the client to choose from
2. (optional) incorporates alternate aesthetic into framework if the client desires

design development

1. present optimal outputs from generative framework to client
2. (optional) incorporate feedback into framework if options do not satisfy aesthetic tastes

design documentation

1. reviews output framework drawings to ensure accuracy
2. (optional) makes modifications to drawings if client requests unique details

construction administration

1. recommends residential builder after bidding
2. (optional) construction site visits to ensure built work matches design drawings

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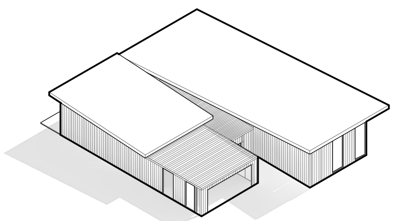
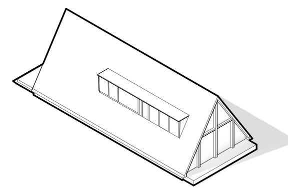


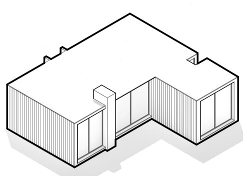
split - plan leasing model:

this house design embraces contemporary living with the incorporation of a split plan to accomodate airbnb leasing, and incremental growth.



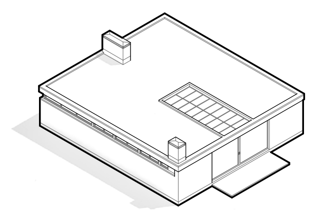
micro - house:

micro - house is designed to afford comfortable living for small family needs. various dimensions of the home are adjusted to suite desired optimized aspects.



minimal traditional model:

the minimal traditional model is designed to be built inexpensively and quickly through minimal design. Orientation and form of the house are subject to adjust through optimization.



art moderne leasing model:

the art moderne house accomodates an adjacent leasing space to eventually be grown into, as the family expands and can afford the additional space.

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select model

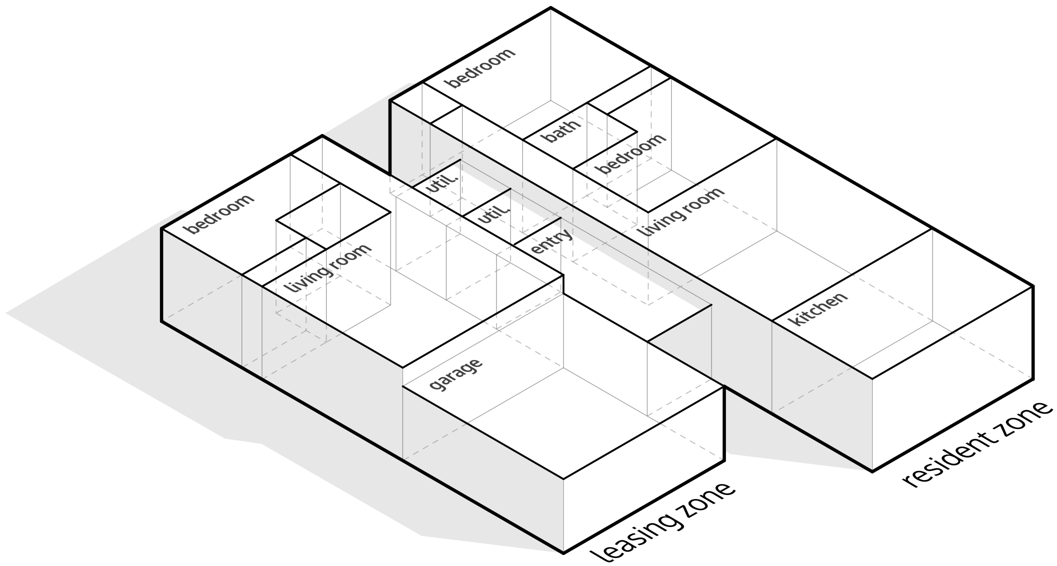
the generative framework can be adjusted at numerous parameters, but as a rule will remain consistent with the following design logic in plan

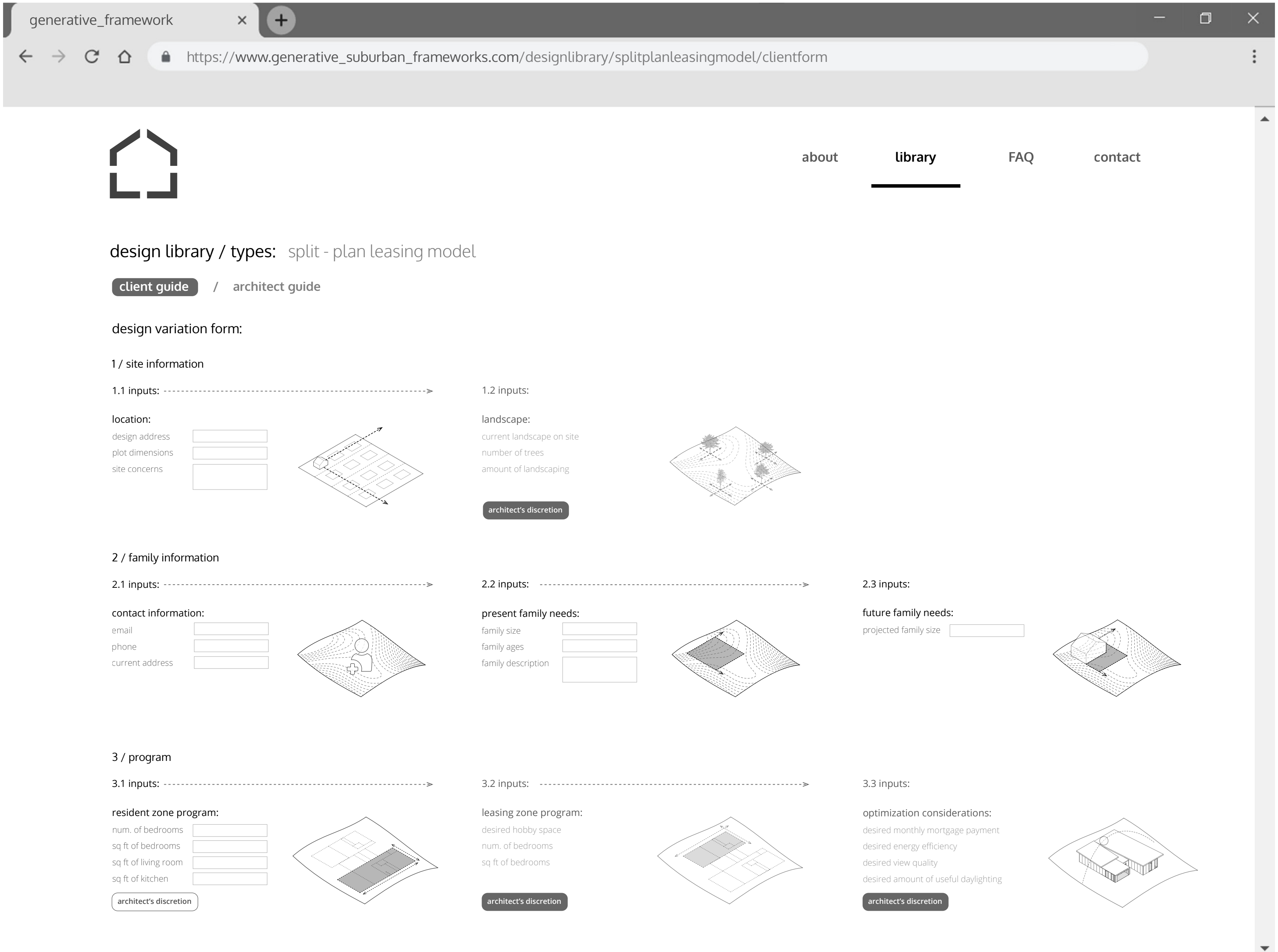
changing parameters:

resident zone proportion ratio
entry zone proportion ratio
airbnb zone proportion ratio
roof pitch
roof offset
roof thickness
roof direction
patio 1 length
patio 2 length
resident zone glazing ratios
airbnb zone glazing ratios
resident zone height
airbnb zone height
garage height
entry zone height
program square footage

available quantitative objectives:

view quality
ventilation performance
useful daylighting
utility cost
construction cost
material waste

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client guide / architect guide
design variation form:
1 / site information
1.1 inputs:
location:
design address
plot dimensions
site concerns
1.2 inputs:
landscape:
current landscape on site
number of trees
amount of landscaping
architect's discretion
2 / family information
2.1 inputs:
contact information:
email
phone
current address
2.2 inputs:
present family needs:
family size
family ages
family description
2.3 inputs:
future family needs:
projected family size
3 / program
3.1 inputs:
resident zone program:
num. of bedrooms
sq ft of bedrooms
sq ft of living room
sq ft of kitchen
architect's discretion
3.2 inputs:
leasing zone program:
desired hobby space
num. of bedrooms
sq ft of bedrooms
architect's discretion
3.3 inputs:
optimization considerations:
desired monthly mortgage payment
desired energy efficiency
desired view quality
desired amount of useful daylighting
architect's discretion

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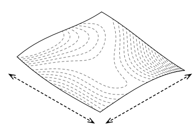
site:

1 / site topography generator

1.1 inputs:

site size:

- design location
- distance x
- distance y
- detail level

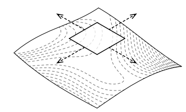


1.2 inputs:

design location:

- location x
- location y

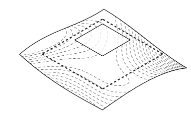
optimizing parameters



1.3 inputs:

home boundary:

- location x
- location y
- distance x
- distance y



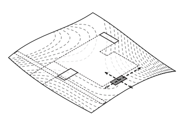
2 / patio sizes

2.1 inputs:

patio 1 parameters:

- location x
- dimension x
- dimension y
- thickness

optimizing parameters

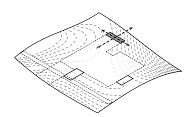


2.2 inputs:

patio 2 parameters:

- location x
- dimension x
- dimension y
- thickness

optimizing parameters

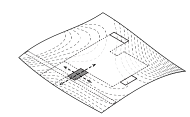


2.3 inputs:

entry parameters:

- dimension y
- thickness

optimizing parameters



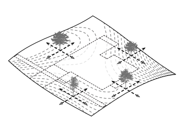
3 / landscaping

3.1 inputs:

tree population:

- number of trees
- dbh of tree
- location x
- location y

optimizing parameters

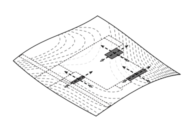


3.2 inputs:

landscaping beds, zone 1:

- location x
- dimension x
- dimension y

optimizing parameters

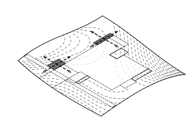


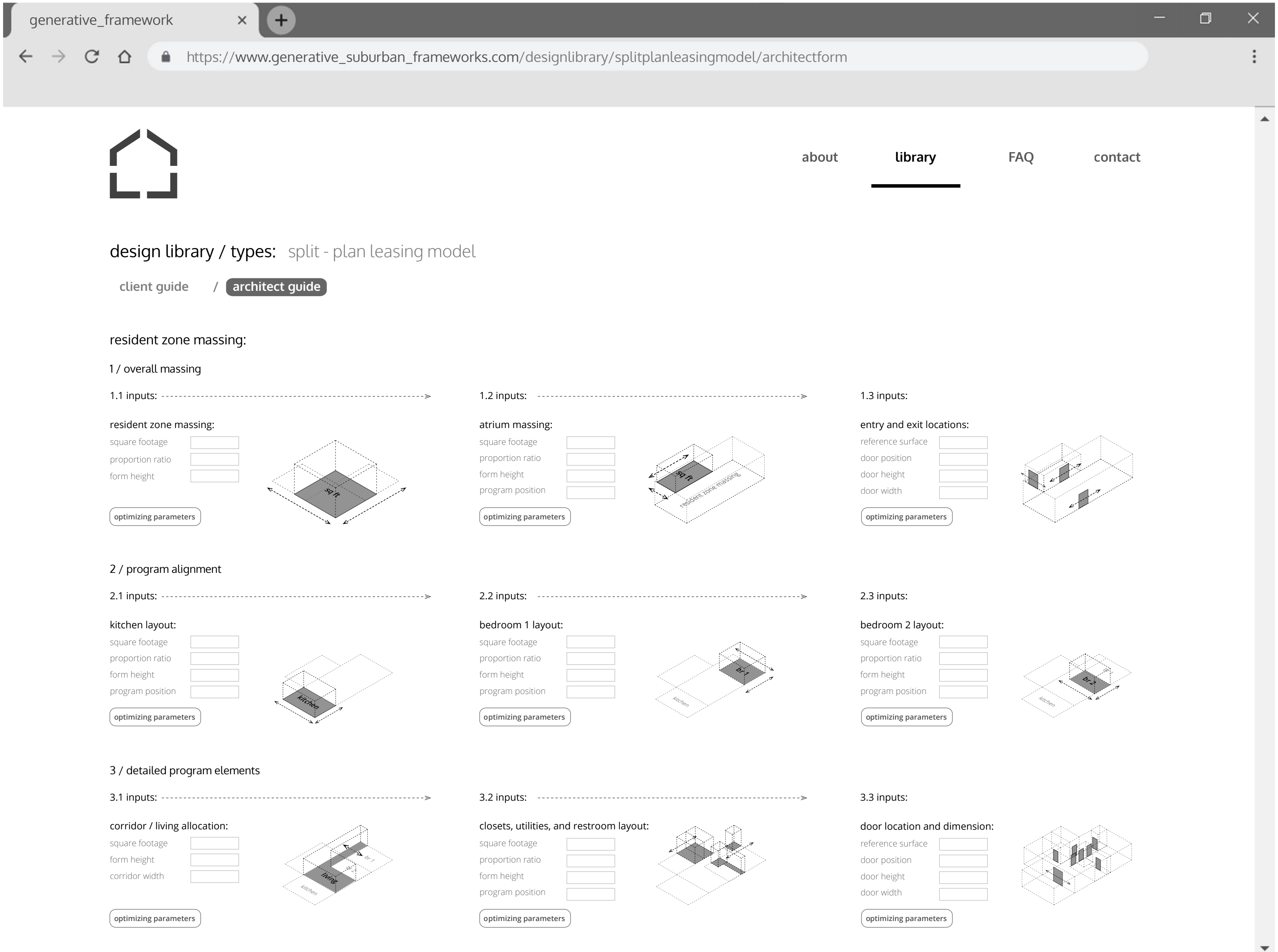
3.3 inputs:

landscaping beds, zone 2:

- location x
- dimension x
- dimension y

optimizing parameters

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resident zone massing:
1 / overall massing
1.1 inputs:
resident zone massing:
square footage
proportion ratio
form height
optimizing parameters
1.2 inputs:
atrium massing:
square footage
proportion ratio
form height
program position
optimizing parameters
1.3 inputs:
entry and exit locations:
reference surface
door position
door height
door width
optimizing parameters
2 / program alignment
2.1 inputs:
kitchen layout:
square footage
proportion ratio
form height
program position
optimizing parameters
2.2 inputs:
bedroom 1 layout:
square footage
proportion ratio
form height
program position
optimizing parameters
2.3 inputs:
bedroom 2 layout:
square footage
proportion ratio
form height
program position
optimizing parameters
3 / detailed program elements
3.1 inputs:
corridor / living allocation:
square footage
form height
corridor width
optimizing parameters
3.2 inputs:
closets, utilities, and restroom layout:
square footage
proportion ratio
form height
program position
optimizing parameters
3.3 inputs:
door location and dimension:
reference surface
door position
door height
door width
optimizing parameters

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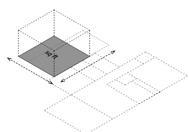
leasing zone massing:

1 / overall massing

1.1 inputs:

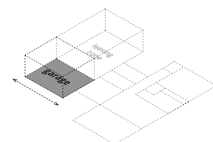
leasing zone massing:
- square footage
- proportion ratio
- form height
- program position

optimizing parameters



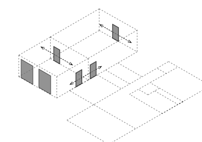
1.2 inputs:

garage massing:
- 1 or 2 car
- form height



1.3 inputs:

entry and exit locations:
- reference surface
- door position
- door height
- door width

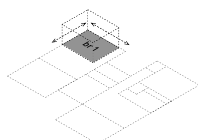


2 / program alignment

2.1 inputs:

bedroom 1 layout:
- square footage
- proportion ratio
- form height
- program position

optimizing parameters

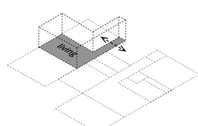


3 / detailed program elements

3.1 inputs:

corridor / living allocation:
- square footage
- form height
- corridor width

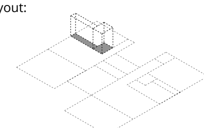
optimizing parameters



3.2 inputs:

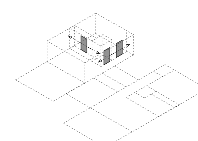
closets, utilities, and restroom layout:
- square footage
- proportion ratio
- form height
- program position

optimizing parameters



3.3 inputs:

door location and dimension:
- reference surface
- door position
- door height
- door width



generative_framework

https://www.generative_suburban_frameworks.com/designlibrary/splitplanleasingmodel/architectform

about library FAQ contact

design library / types: split - plan leasing model

client guide / **architect guide**

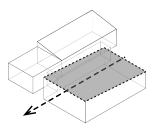
design elements:

1 / roof pitch

1.1 inputs:

pitch direction, resident zone:

pitch direction

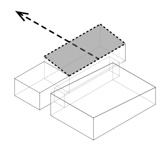


optimizing parameters

1.2 inputs:

pitch direction, lease zone:

pitch direction



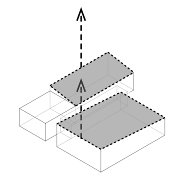
optimizing parameters

1.3 inputs:

roof angle:

pitch height 1

pitch height 2



optimizing parameters

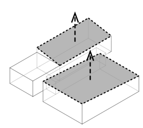
2 / roof design

2.1 inputs:

roof thickness:

thickness 1

thickness 2



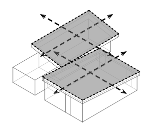
optimizing parameters

2.2 inputs:

roof overhang:

overhang dim 1

overhang dim 2



optimizing parameters

3 / glazing elements

3.1 inputs:

glazing ratio, resident zone:

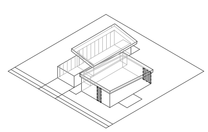
glazing location

glazing ratio (north)

glazing ratio (south)

glazing ratio (east)

glazing ratio (west)



optimizing parameters

3.2 inputs:

glazing ratio, lease zone:

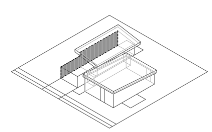
glazing location

glazing ratio (north)

glazing ratio (south)

glazing ratio (east)

glazing ratio (west)



optimizing parameters

3.3 inputs:

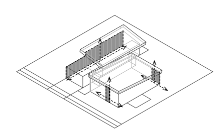
window aesthetic:

window height

window width

sill height

offset



optimizing parameters

generative_framework

https://www.generative_suburban_frameworks.com/designlibrary/splitplanleasingmodel/architectform

design library / types: split - plan leasing model

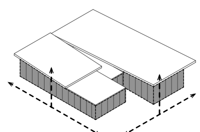
client guide / **architect guide**

construction output:

1 / envelope structure

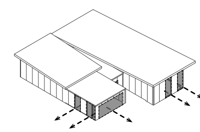
1.1 inputs:

sip panel generation:
- sip panel width
- sip panel height
- wall thickness



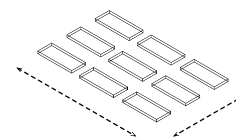
1.2 inputs:

cutouts for openings:
- structure offset



1.3 inputs:

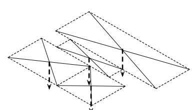
component list and cost:
- spacing of list
- cost per unit
- cons. cost per unit



2 / foundation

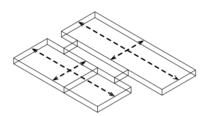
2.1 inputs:

foundation wall generation:
- wall thickness
- wall offset
- foundation depth



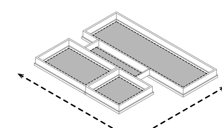
2.2 inputs:

footing generation:
- footing depth
- footing offset



2.3 inputs:

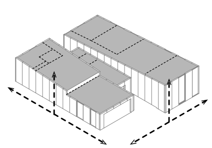
component list and cost:
- cost per unit
- cons. cost per unit



3 / interior wall structure

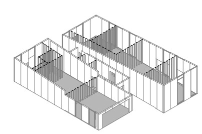
3.1 inputs:

wood stud generation:
- stud dimension
- stud spacing
- wall thickness



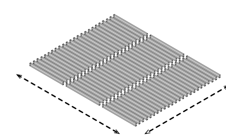
3.2 inputs:

cutouts for openings:
- structure offset



3.3 inputs:

component list and cost:
- spacing of list
- cost perunit
- cons. cost per unit



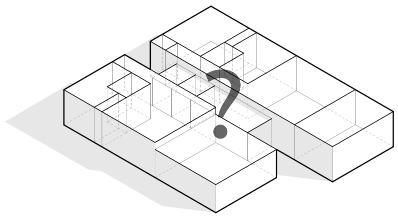
05 / results

To test the workflow and framework developed through this thesis, client profiles were created. They consist of one family from Lincoln and a single mother in Phoenix, to serve as examples and afford comparisons between different family models and climates. This method of testing also demonstrates the framework's capacity to improve upon the current system by incorporating more contextual design considerations based upon the differing conditions. Both profiles developed were set to undergo a similar optimization, with differences in the targets associated with them. The first profile, the family from Lincoln Nebraska, seeks to optimize for the lowest possible utility cost, a home value of $270000, a renting value for the attached leasing space of $785 per month, and lastly an improved spatial quality in the living rooms of both the main and leasing space, which is generally achieved through adjustment of the height and direction of the roof pitch parameters. The results output from the optimization show that each of these objectives are able to be optimized for, with utility cost and living room spatial quality showing incremental improvements over the 15 generations, and the home and leasing value being solved very quickly within the first few generations.

The second test of the optimization for the smaller family located in Phoenix, Arizona, shows that the framework is able to adjust to alternate family models and climates. This optimization had the same overall objectives, with the home and leasing value being lowered to accommodate the smaller family size, and the qualitative variable being adjusted to define the spatial quality of the bedrooms instead of the living rooms. The results from this test are very similar to the first in that they show incremental improvements in objectives related to energy and quality and the quick development of solutions related to the specified financial criteria.

The optimized models from both simulations were also compared with a normative model, whose plan was acquired from the website of a local builder and put through the same tests as the generative models to ensure they outperform present conditions. Not only can the generative framework models be built for an estimated lower price, but they also perform far better in terms of their energy performance. The generative models in Lincoln tested an annual utility cost at $2.87 per square foot, and the normative models showed a cost of $4.36 per square foot. When you also consider the leasing value associated with the generative models, savings of $125,780 can be reached after 10 years of living within one of the pareto optimal homes in Lincoln. Similarly, the Phoenix generative models allowed for an annual utility cost of $2.16 per square foot, with the normative model outputting $4.07 per square foot. With consideration of the attached leasing space value, this amounts to 10 year savings of $125,790.

The generative framework also succeeded in the output of the home’s structure, associated component list, and the breakdown of costs with each area of construction for both simulations. This output is crucial to ensure the generative framework is able to maintain the cost and time of present conditions, while still adding the involvement of architects and greater design consideration. Lastly, the pareto optimal solutions within both simulations all showed subtle variation, which hints toward convergence of the models into single optimal solutions, yet still present the opportunity for the client to select from a range of options despite already receiving a customized model.



generative framework workflow example #1:

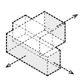
client profile #1

location: lincoln, nebraska

plan: split - plan leasing model

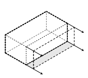
description: married couple with children, seeking a space to accommodate their elderly parents and oldest son when he visits from college

optimization objectives:



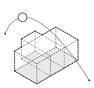
❶ design to set home value, desired at $270000 (quantitative)

family is able to afford a larger home, but would still hope for the cost to fall around $270000 so mortgage payments are readily payable for when their son moves to college



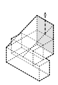
❷ design to set leasing space value, desired at $785 per month (quantitative)

client would benefit from additional considerations of leasing space and airbnb tenants as they will have extra space when their son and parents aren't visiting



❸ lower annual energy / utility costs (quantitative)

client would like to lower the annual utility costs and energy use associated with the home, to lower their environmental footprint and personal costs



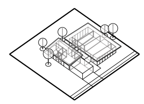
❹ optimal lighting / spatial quality of living rooms (qualitative)

architect wants to ensure appropriate spatial / lighting qualities for the living spaces of the home, which relates to the orientation of the pitch in regard to those rooms

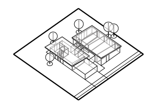
generative framework adjustments:

-adjusting location of the home on the site
-adjusting the number and size of rooms in the home

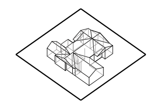
optimization results



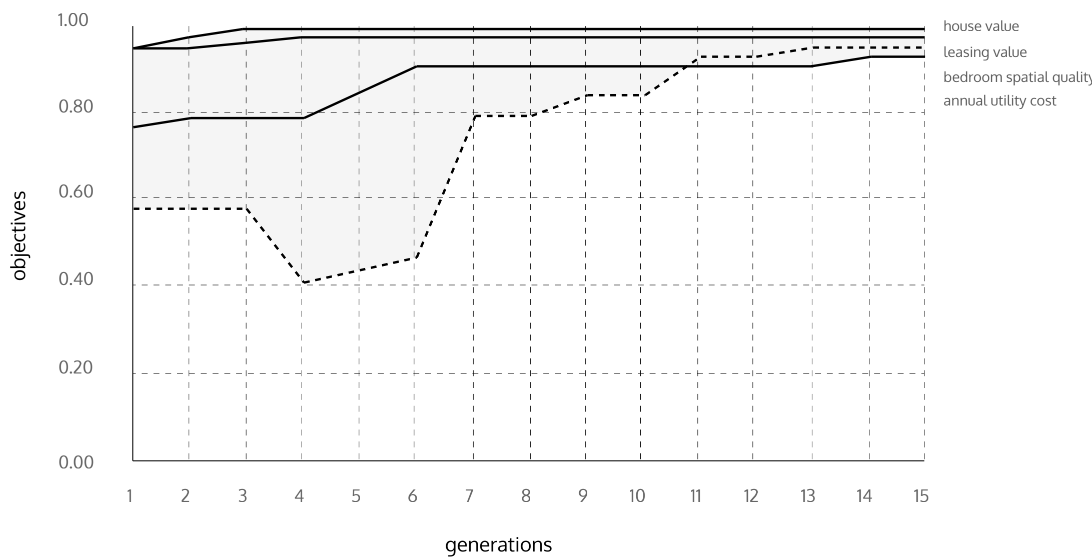
pareto solution 7.14
annual utility cost: $2.87 / sf
home value: $268,132
lease value: $775 / month



pareto solution 9.04
annual utility cost: $2.22 / sf
home value: $278,993
lease value: $852 / month



normative model
annual utility cost: $4.36 / sf
home value: $285,551



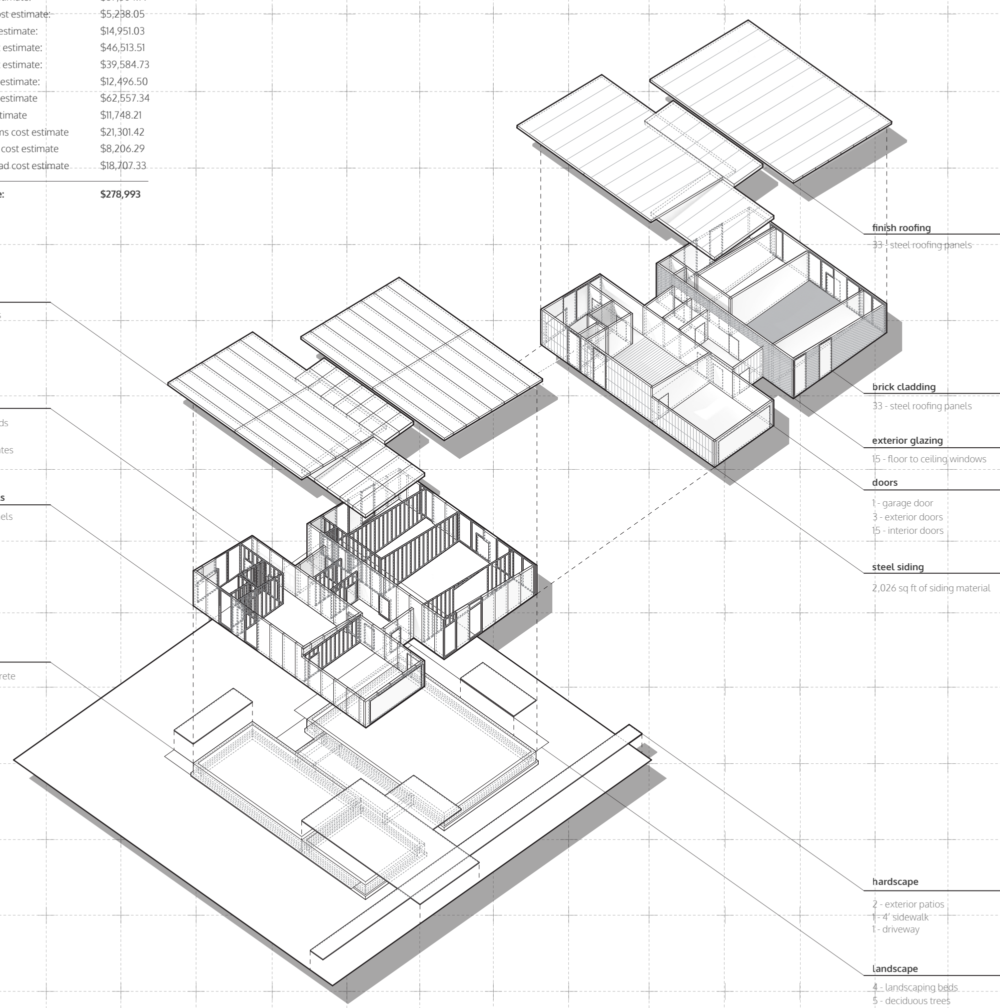
client #1: 9.04 components output

location: lincoln, nebraska

plan: split - plan leasing model

cost estimating:

site work cost estimate:	$5,462.54
foundation cost estimate:	$37,364.79
interior framing cost estimate:	$5,238.05
exterior wall cost estimate:	$14,951.03
roof structure cost estimate:	$46,513.51
exterior finish cost estimate:	$39,584.73
roofing finish cost estimate:	$12,496.50
interior finish cost estimate	$62,557.34
specialties cost estimate	$11,748.21
mechanical systems cost estimate	$21,301.42
electrical systems cost estimate	$8,206.29
contractor overhead cost estimate	$18,707.33
total home value:	**$278,993**



client #1 optimization population

location: lincoln, nebraska

plan: split - plan leasing model

generative framework adjustments:

-adjusting location of the home on the site

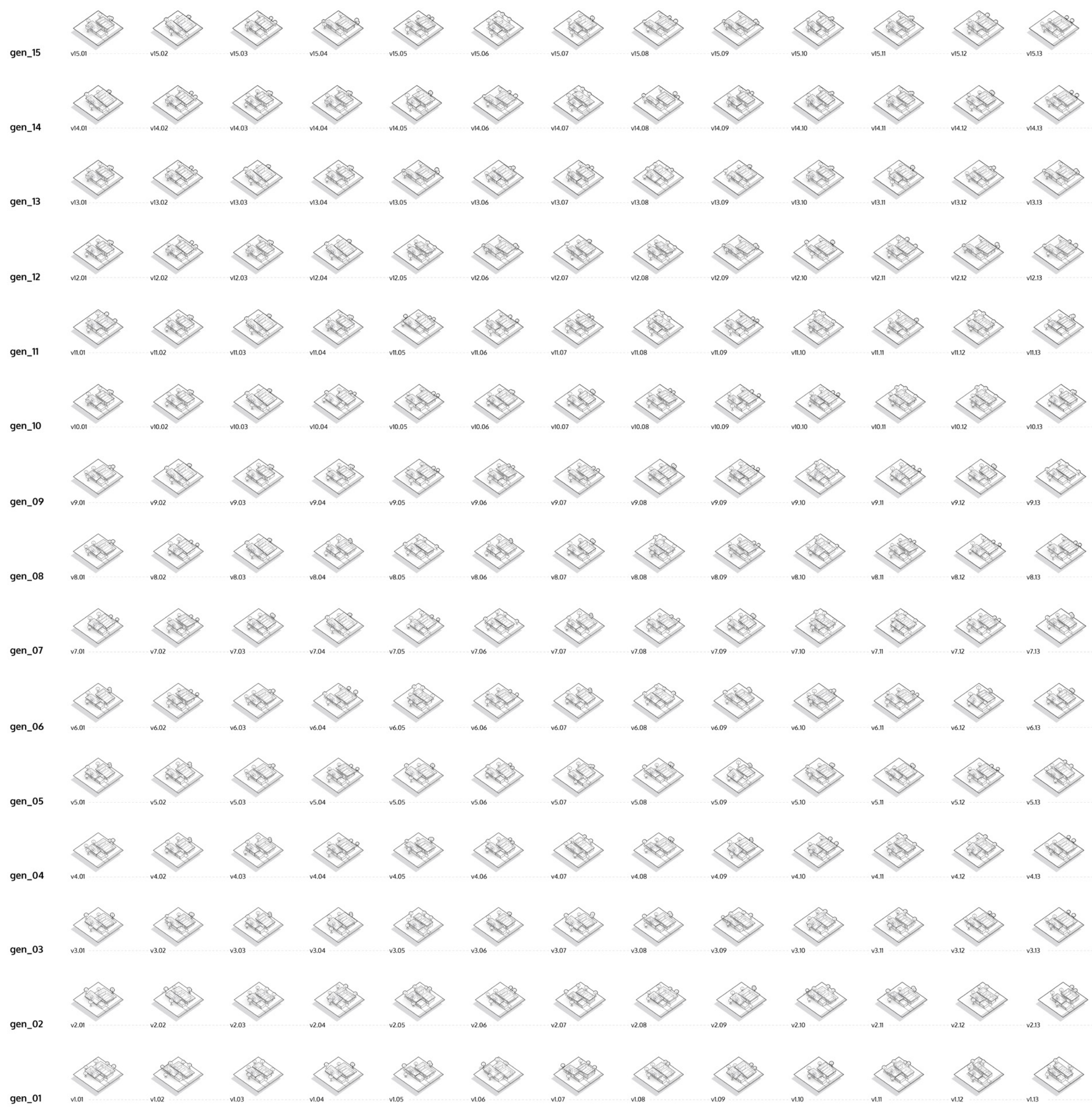
-adjusting the number and size of rooms in the home

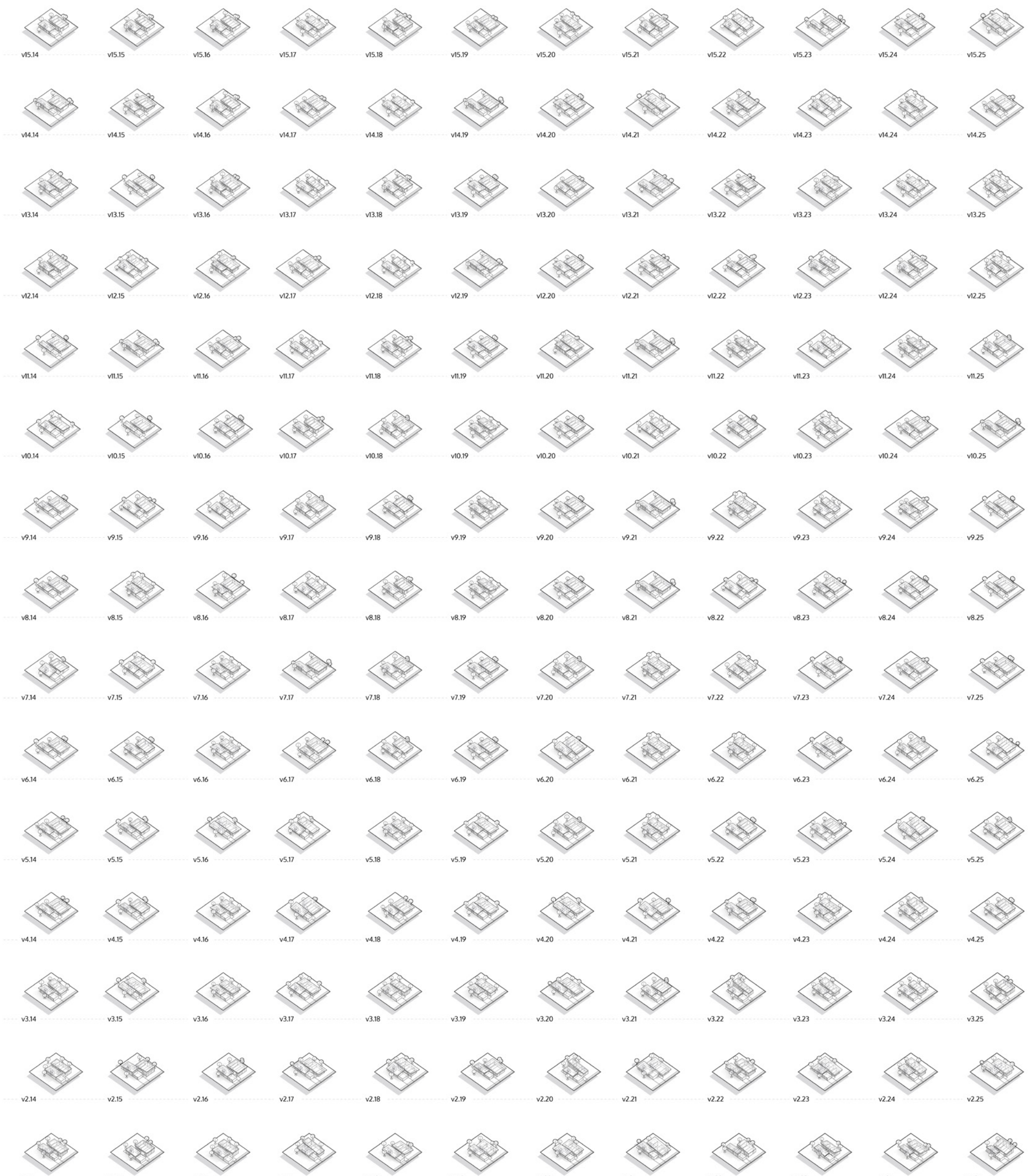
optimization objectives:

1. design to set home value, desired at $185000 (quantitative)
2. design to set leasing space value, desired at $650 per month (quantitative)
3. lower annual energy / utility costs (quantitative)
4. optimal lighting / spatial quality of bedrooms (qualitative)

changing parameters:

- resident zone square footage
- resident zone dimension
- resident zone massing height
- kitchen square footage
- bedroom 1 square footage
- bedroom 2 square footage
- atrium zone square footage
- atrium zone dimension
- atrium massing height
- atrium massing position
- leasing zone square footage
- leasing zone dimension
- leasing zone massing position
- garage height
- patio 1 depth
- patio 2 depth
- tree 1 location
- tree 1 diameter at breast height
- tree 2 location
- tree 2 diameter at breast height
- tree 3 location
- tree 3 diameter at breast height
- tree 4 location
- tree 4 diameter at breast height
- tree 5 location
- tree 5 diameter at breast height
- roof 1 overhang
- roof 1 direction
- roof 1 pitch height
- roof 1 thickness
- roof 2 overhang
- roof 2 direction
- roof 2 pitch height
- roof 2 thickness
- glazing 1 ratio
- glazing 1 location
- glazing 2 ratio
- glazing 2 location
- glazing 3 ratio
- glazing 3 location
- glazing 4 ratio
- glazing 4 location
- glazing 5 ratio
- glazing 5 location

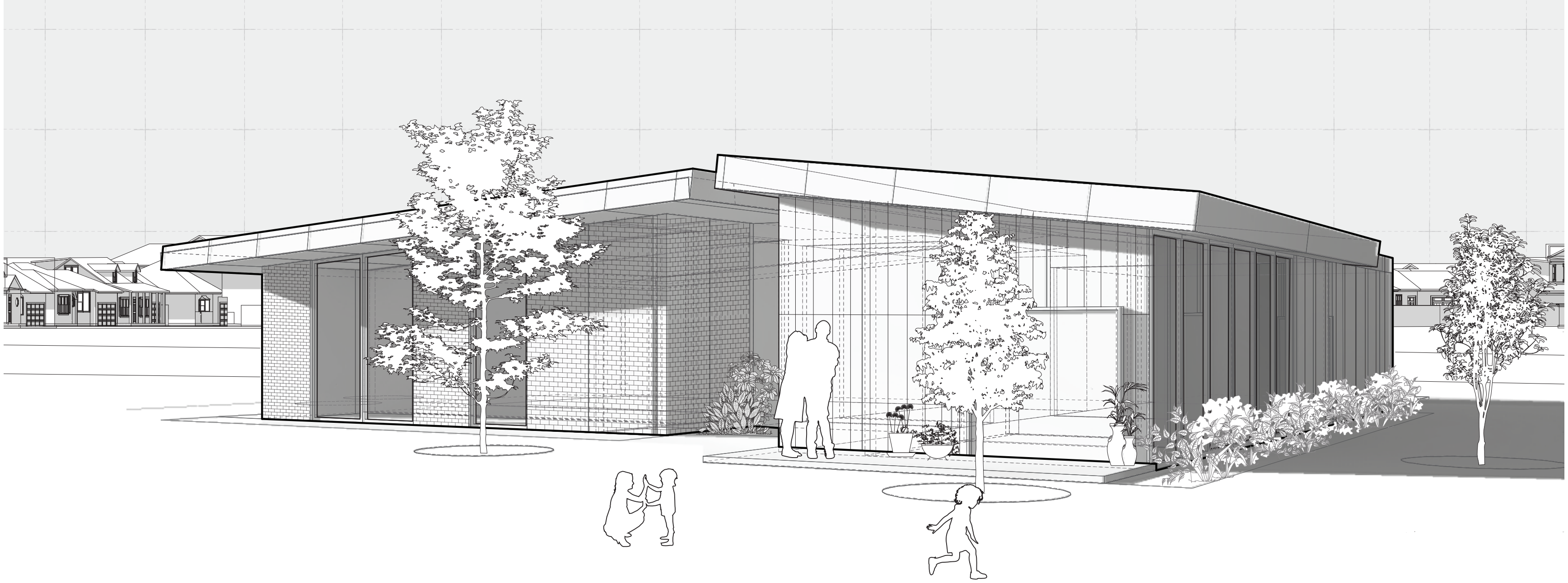



v15.14 v15.15 v15.16 v15.17 v15.18 v15.19 v15.20 v15.21 v15.22 v15.23 v15.24 v15.25
v14.14 v14.15 v14.16 v14.17 v14.18 v14.19 v14.20 v14.21 v14.22 v14.23 v14.24 v14.25
v13.14 v13.15 v13.16 v13.17 v13.18 v13.19 v13.20 v13.21 v13.22 v13.23 v13.24 v13.25
v12.14 v12.15 v12.16 v12.17 v12.18 v12.19 v12.20 v12.21 v12.22 v12.23 v12.24 v12.25
v11.14 v11.15 v11.16 v11.17 v11.18 v11.19 v11.20 v11.21 v11.22 v11.23 v11.24 v11.25
v10.14 v10.15 v10.16 v10.17 v10.18 v10.19 v10.20 v10.21 v10.22 v10.23 v10.24 v10.25
v9.14 v9.15 v9.16 v9.17 v9.18 v9.19 v9.20 v9.21 v9.22 v9.23 v9.24 v9.25
v8.14 v8.15 v8.16 v8.17 v8.18 v8.19 v8.20 v8.21 v8.22 v8.23 v8.24 v8.25
v7.14 v7.15 v7.16 v7.17 v7.18 v7.19 v7.20 v7.21 v7.22 v7.23 v7.24 v7.25
v6.14 v6.15 v6.16 v6.17 v6.18 v6.19 v6.20 v6.21 v6.22 v6.23 v6.24 v6.25
v5.14 v5.15 v5.16 v5.17 v5.18 v5.19 v5.20 v5.21 v5.22 v5.23 v5.24 v5.25
v4.14 v4.15 v4.16 v4.17 v4.18 v4.19 v4.20 v4.21 v4.22 v4.23 v4.24 v4.25
v3.14 v3.15 v3.16 v3.17 v3.18 v3.19 v3.20 v3.21 v3.22 v3.23 v3.24 v3.25
v2.14 v2.15 v2.16 v2.17 v2.18 v2.19 v2.20 v2.21 v2.22 v2.23 v2.24 v2.25
v1.14 v1.15 v1.16 v1.17 v1.18 v1.19 v1.20 v1.21 v1.22 v1.23 v1.24 v1.25

7.24 render

client profile #1

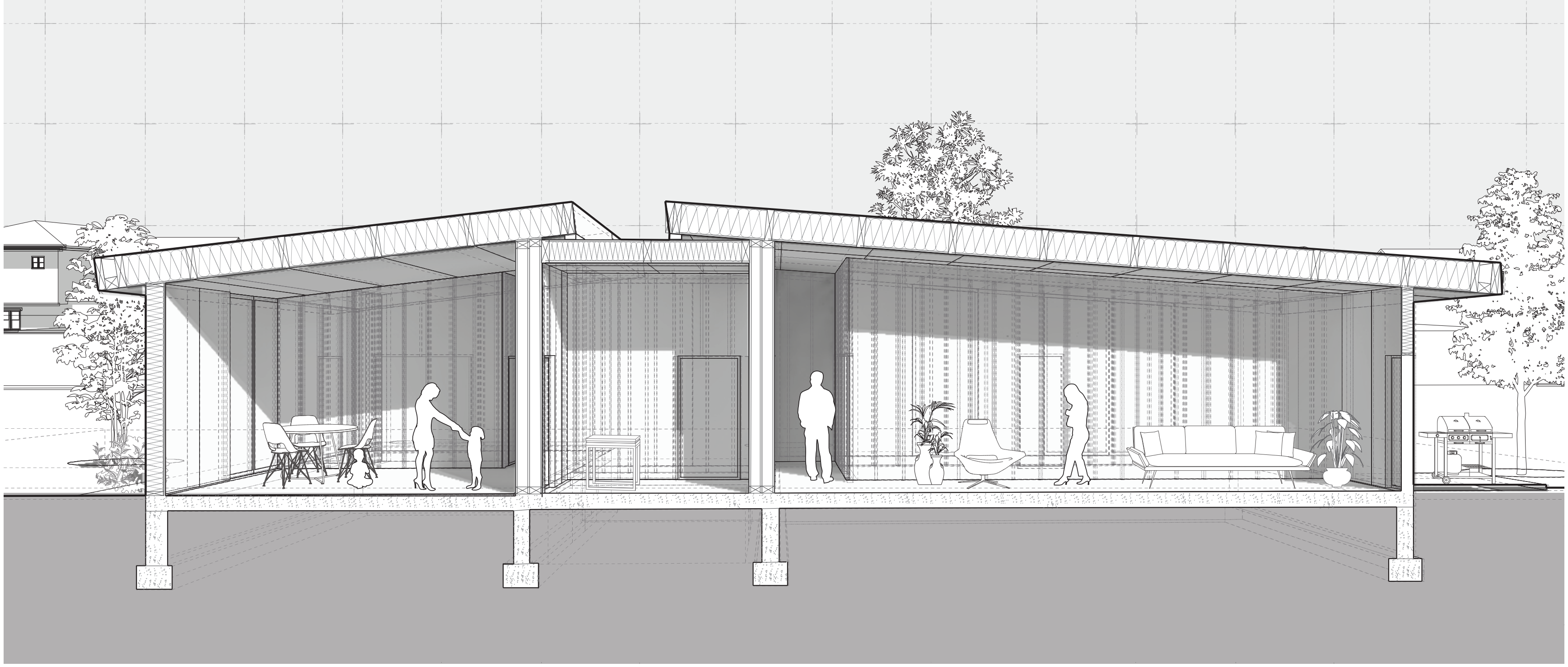
location: lincoln, nebraska
plan: split - plan leasing model

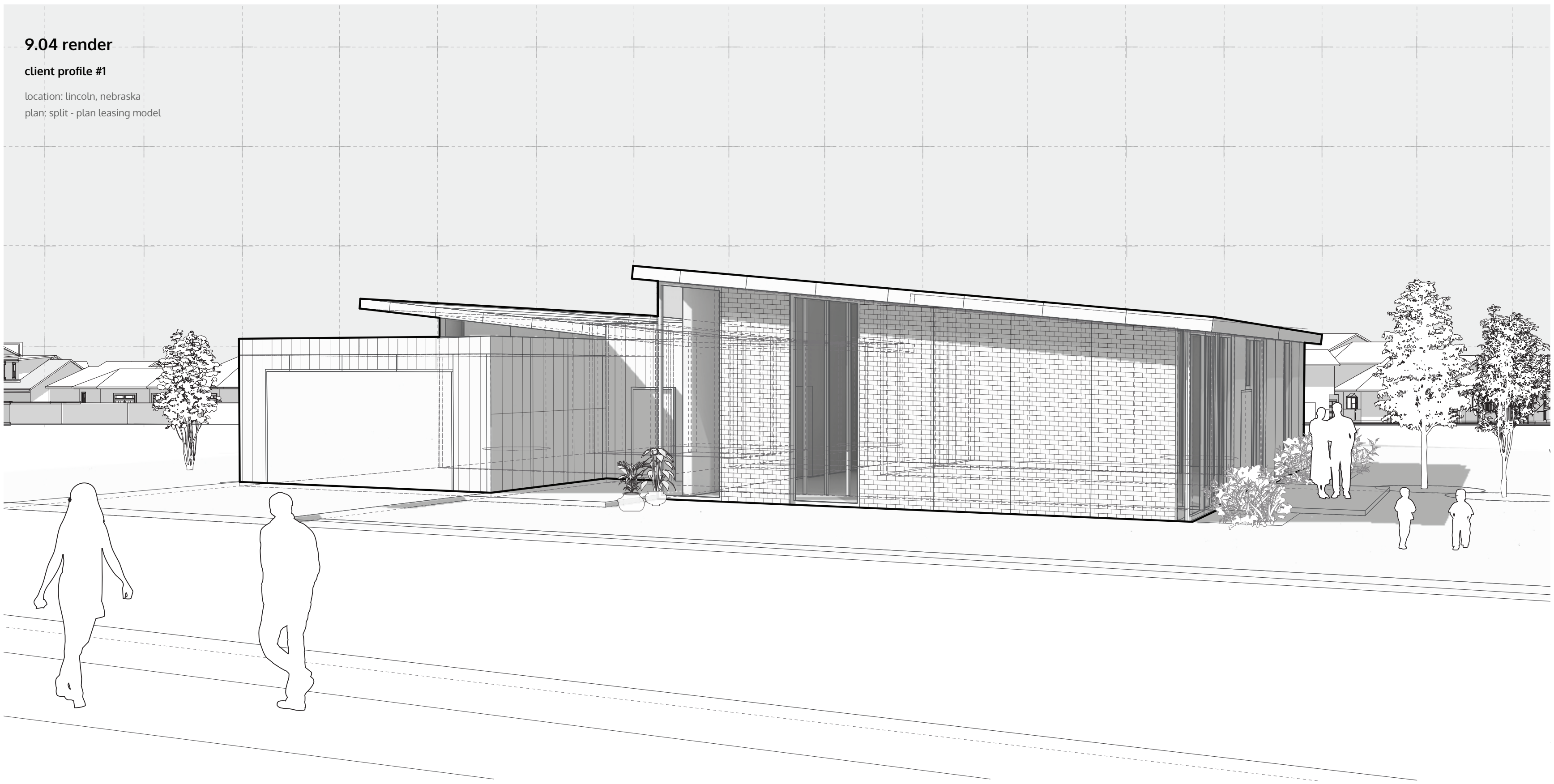


7.24 section perspective

client profile #1

location: lincoln, nebraska
plan: split - plan leasing model

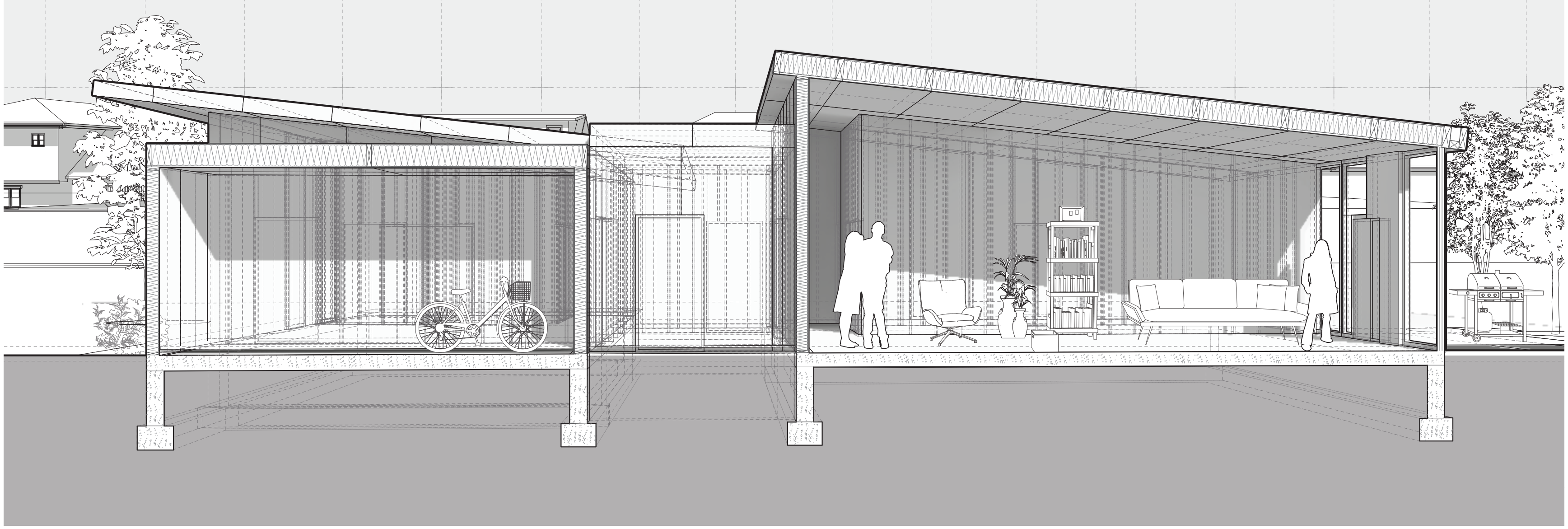


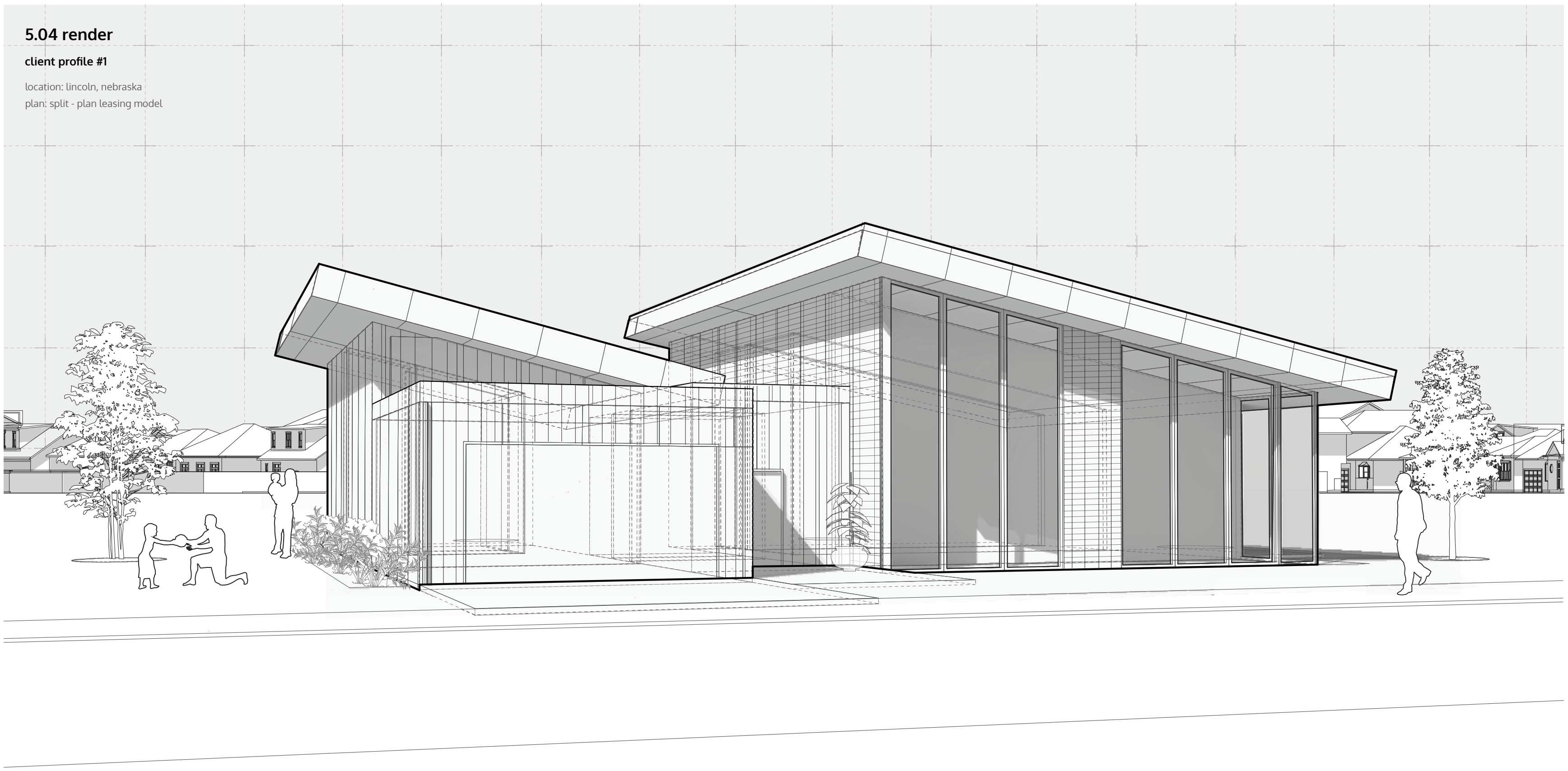

9.04 render
client profile #1
location: lincoln, nebraska
plan: split - plan leasing model

9.04 section perspective

client profile #1

location: lincoln, nebraska
plan: split - plan leasing model





5.04 render

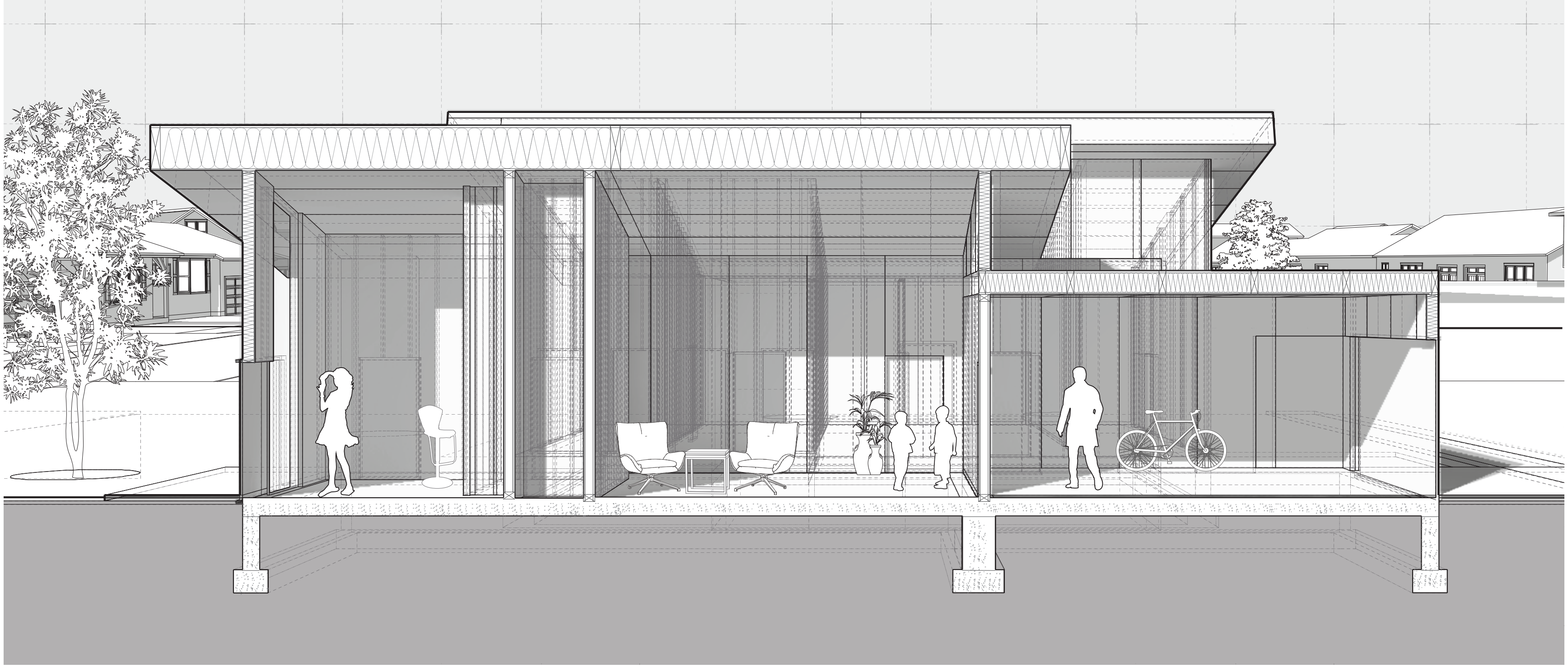
client profile #1

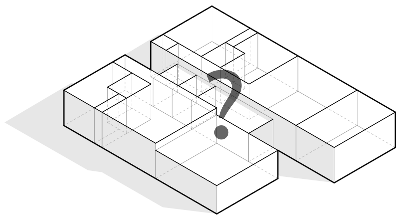
location: lincoln, nebraska
plan: split - plan leasing model

5.04 section perspective

client profile #1

location: lincoln, nebraska
plan: split - plan leasing model





generative framework workflow examples:

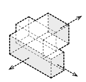
client profile #2

location: phoenix, arizona

plan: split - plan leasing model

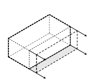
description: single mother, looking to lease out extra space in home to supplement her monthly mortgage payments until her family is large enough to grow into it

optimization objectives:



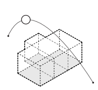
1. design to set home value, desired at $230000 (quantitative)

   requires space to accommodate the growing needs of her family as it develops over the years. However, she would still seek a lower value of the home than usual to afford easier payments



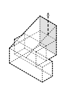
2. design to set leasing space value, desired at $750 per month (quantitative)

   client is looking to lease out the extra space in the home until her family grows and is able to use it. She would like to gain $750 per month from the extra space



3. lower annual energy / utility costs (quantitative)

   client would benefit from optimal daylighting performance to further supplement her ability to pay monthly mortgage costs



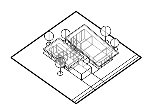
4. optimal lighting / spatial quality of bedrooms (qualitative)

   architect and client both want to ensure appropriate spatial / lighting qualities within the bedrooms, which relates to the orientation of the roof pitch in those areas

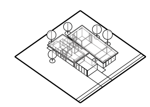
generative framework adjustments:

-adjusting location of the home on the site
-adjusting the number and size of rooms in the home

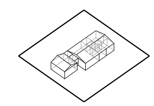
optimization results



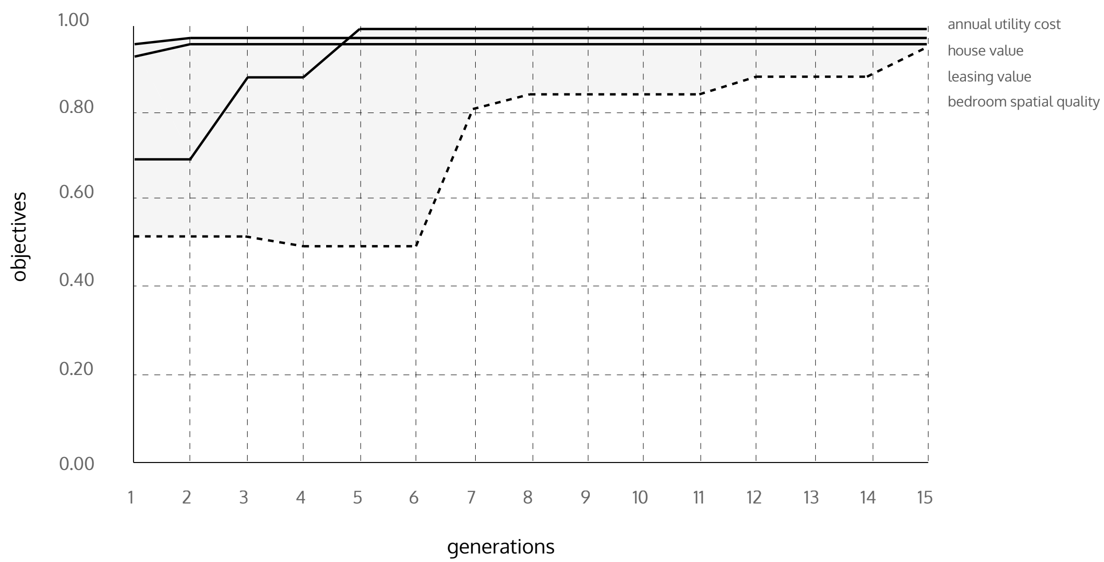
pareto solution 6.03
annual utility cost: $2.16 / sf
home value: $230,697
lease value: $745 / month



pareto solution 12.02
annual utility cost: $2.23 / sf
home value: $228,647
lease value: $759 / month



normative model
annual utility cost: $4.07 / sf
home value: $240,464



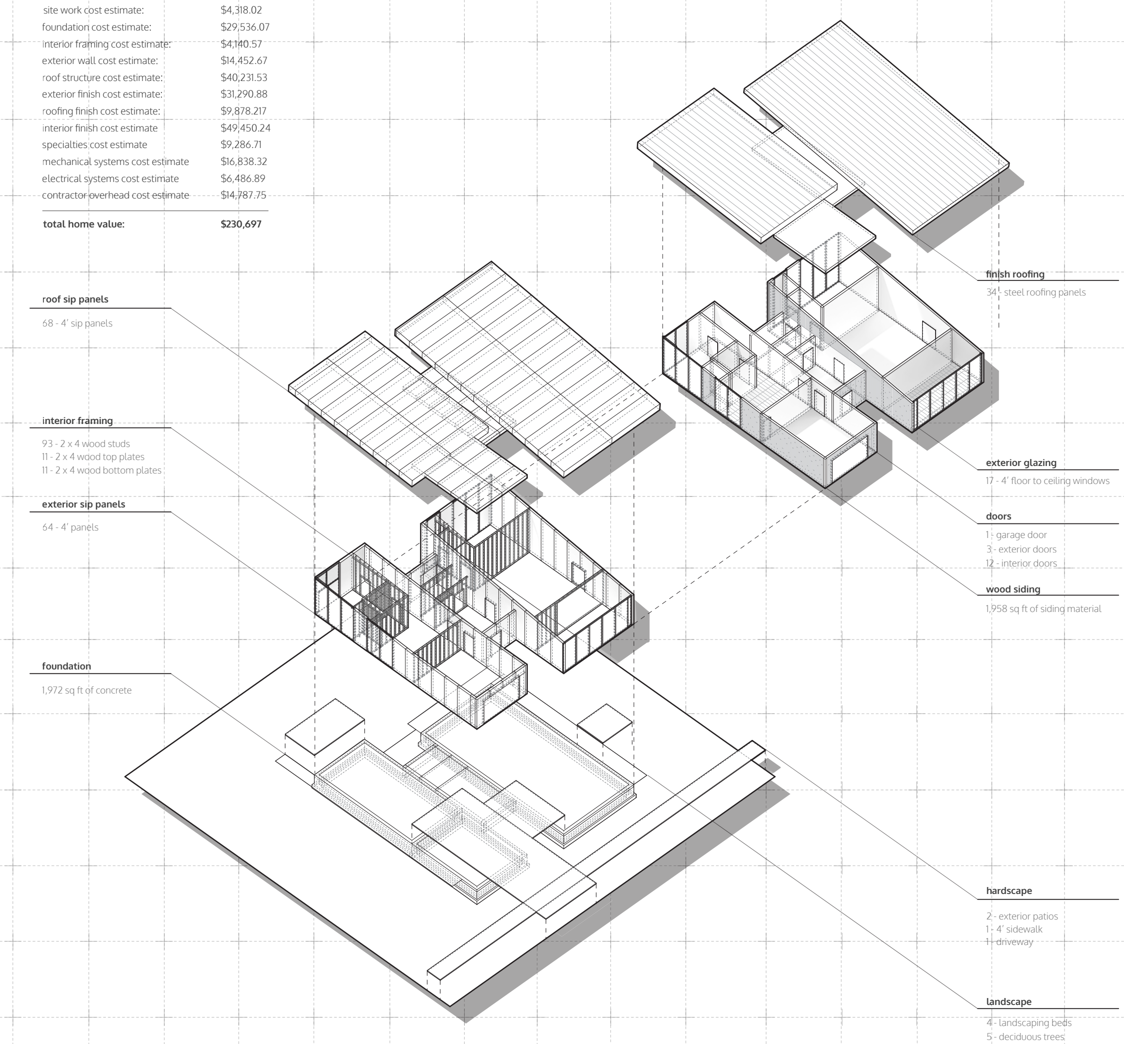
client #2: 6.03 components output

location: phoenix, arizona

plan: split - plan leasing model

cost estimating:

site work cost estimate:	$4,318.02
foundation cost estimate:	$29,536.07
interior framing cost estimate:	$4,140.57
exterior wall cost estimate:	$14,452.67
roof structure cost estimate:	$40,231.53
exterior finish cost estimate:	$31,290.88
roofing finish cost estimate:	$9,878.217
interior finish cost estimate	$49,450.24
specialties cost estimate	$9,286.71
mechanical systems cost estimate	$16,838.32
electrical systems cost estimate	$6,486.89
contractor overhead cost estimate	$14,787.75
total home value:	**$230,697**



client #2 optimization population

location: phoenix, arizona

plan: split - plan leasing model

generative framework adjustments:

-adjusting location of the home on the site

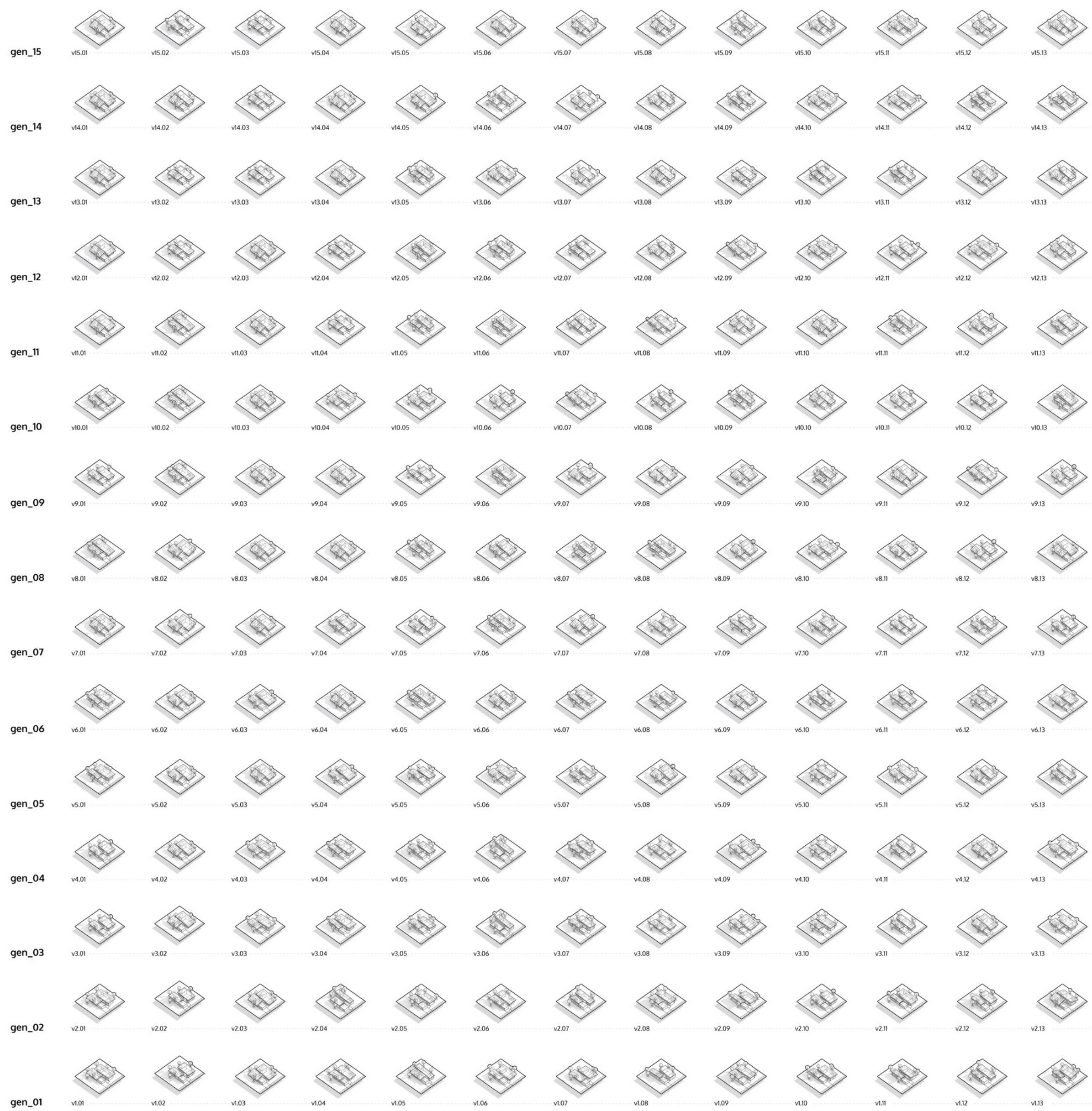
-adjusting the number and size of rooms in the home

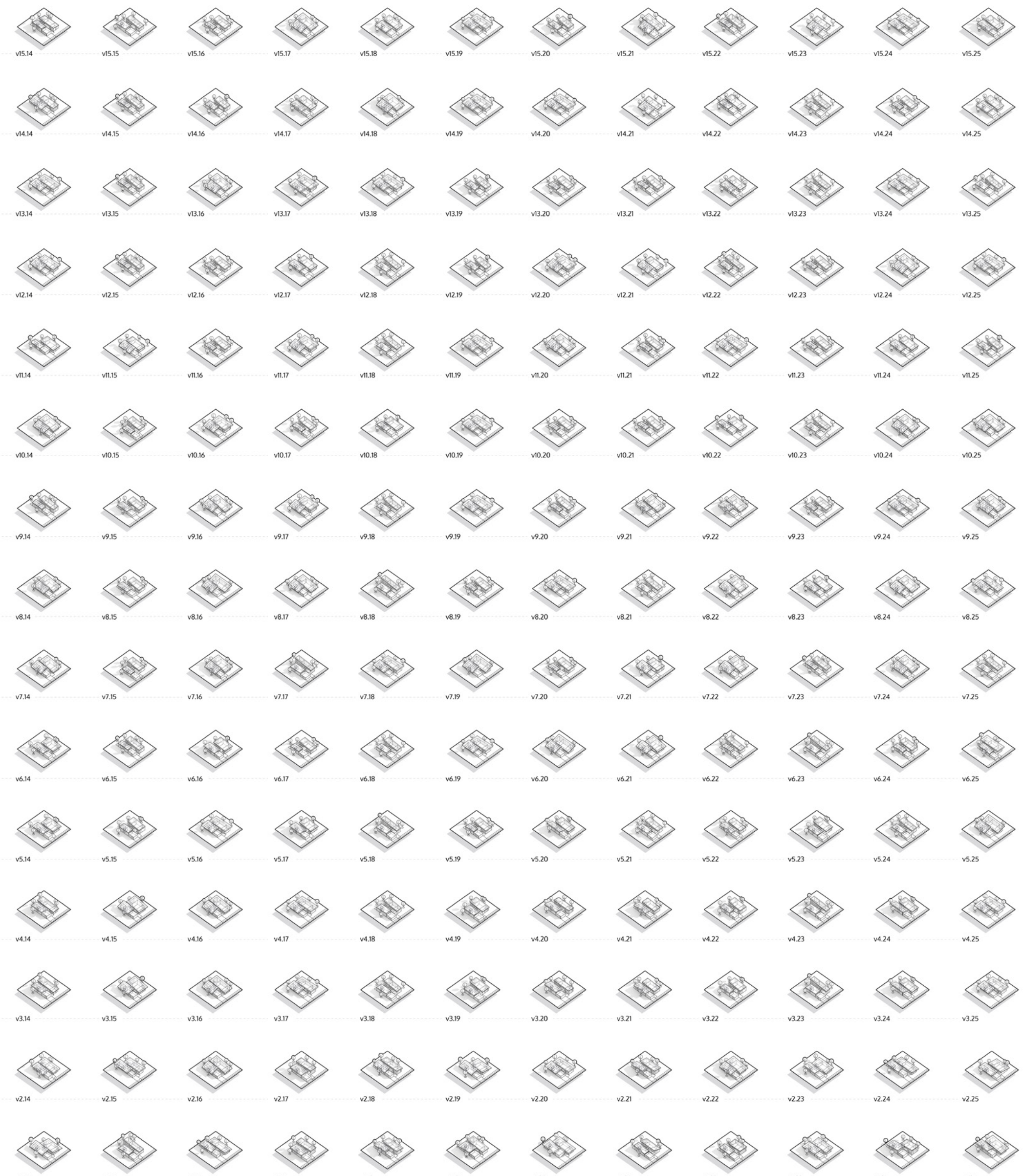
optimization objectives:

1. design to set home value, desired at $185000 (quantitative)
2. design to set leasing space value, desired at $650 per month (quantitative)
3. lower annual energy / utility costs (quantitative)
4. optimal lighting / spatial quality of bedrooms (qualitative)

changing parameters:

- resident zone square footage
- resident zone dimension
- resident zone massing height
- kitchen square footage
- bedroom 1 square footage
- bedroom 2 square footage
- atrium zone square footage
- atrium zone dimension
- atrium massing height
- atrium massing position
- leasing zone square footage
- leasing zone dimension
- leasing zone massing position
- garage height
- patio 1 depth
- patio 2 depth
- tree 1 location
- tree 1 diameter at breast height
- tree 2 location
- tree 2 diameter at breast height
- tree 3 location
- tree 3 diameter at breast height
- tree 4 location
- tree 4 diameter at breast height
- tree 5 location
- tree 5 diameter at breast height
- roof 1 overhang
- roof 1 direction
- roof 1 pitch height
- roof 1 thickness
- roof 2 overhang
- roof 2 direction
- roof 2 pitch height
- roof 2 thickness
- glazing 1 ratio
- glazing 1 location
- glazing 2 ratio
- glazing 2 location
- glazing 3 ratio
- glazing 3 location
- glazing 4 ratio
- glazing 4 location
- glazing 5 ratio
- glazing 5 location

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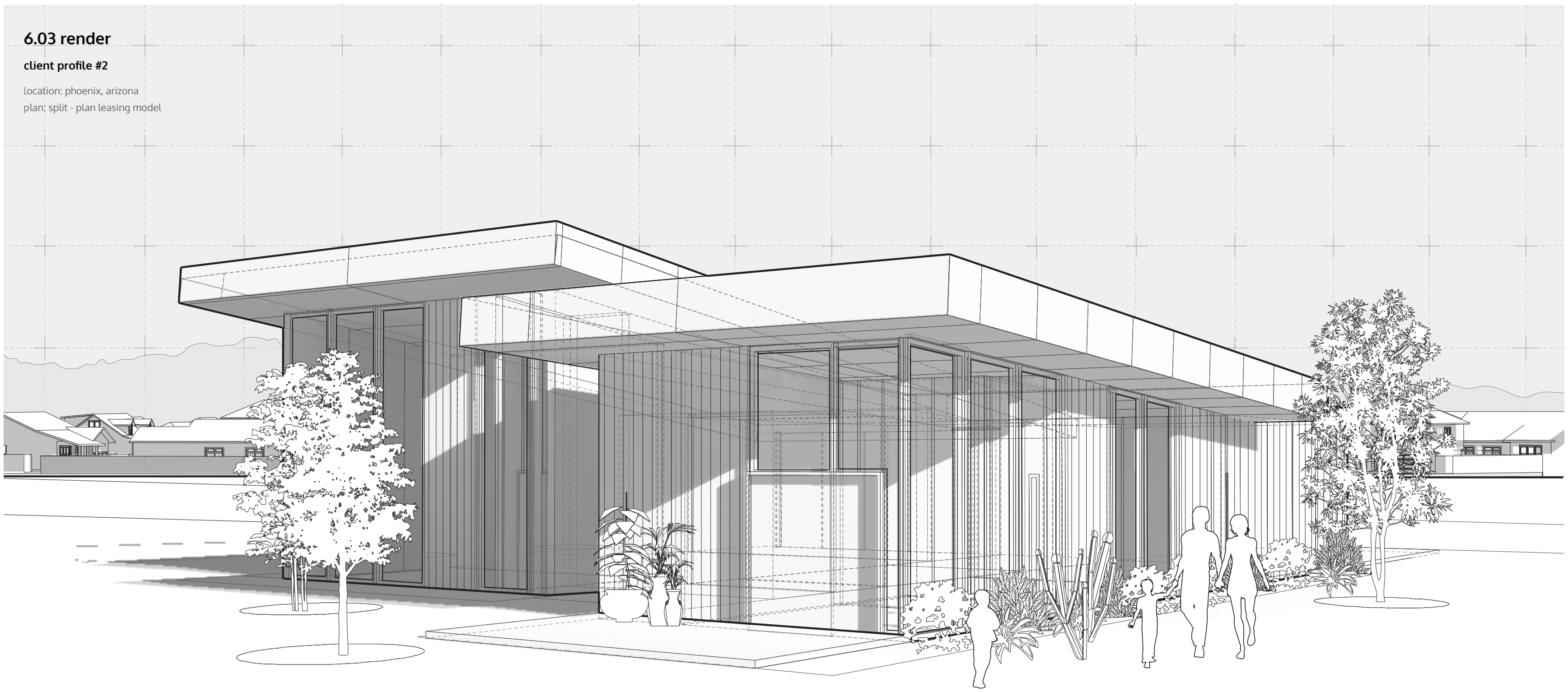
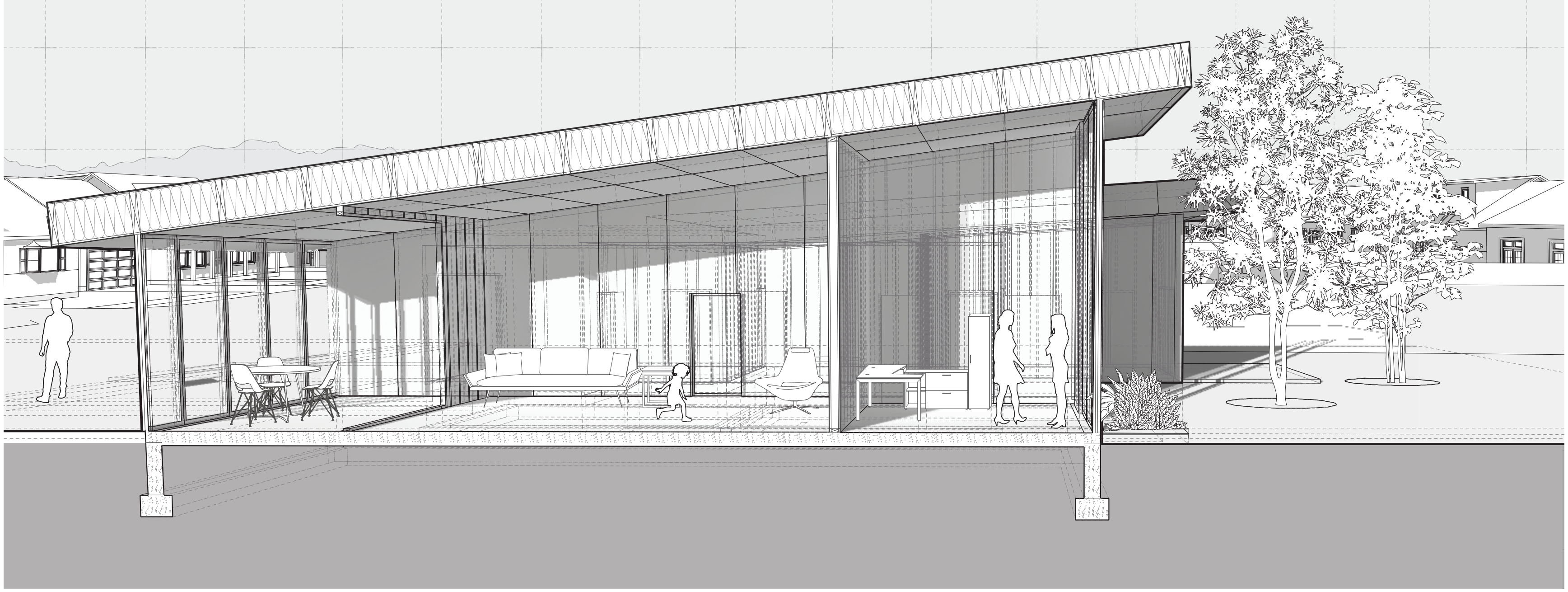
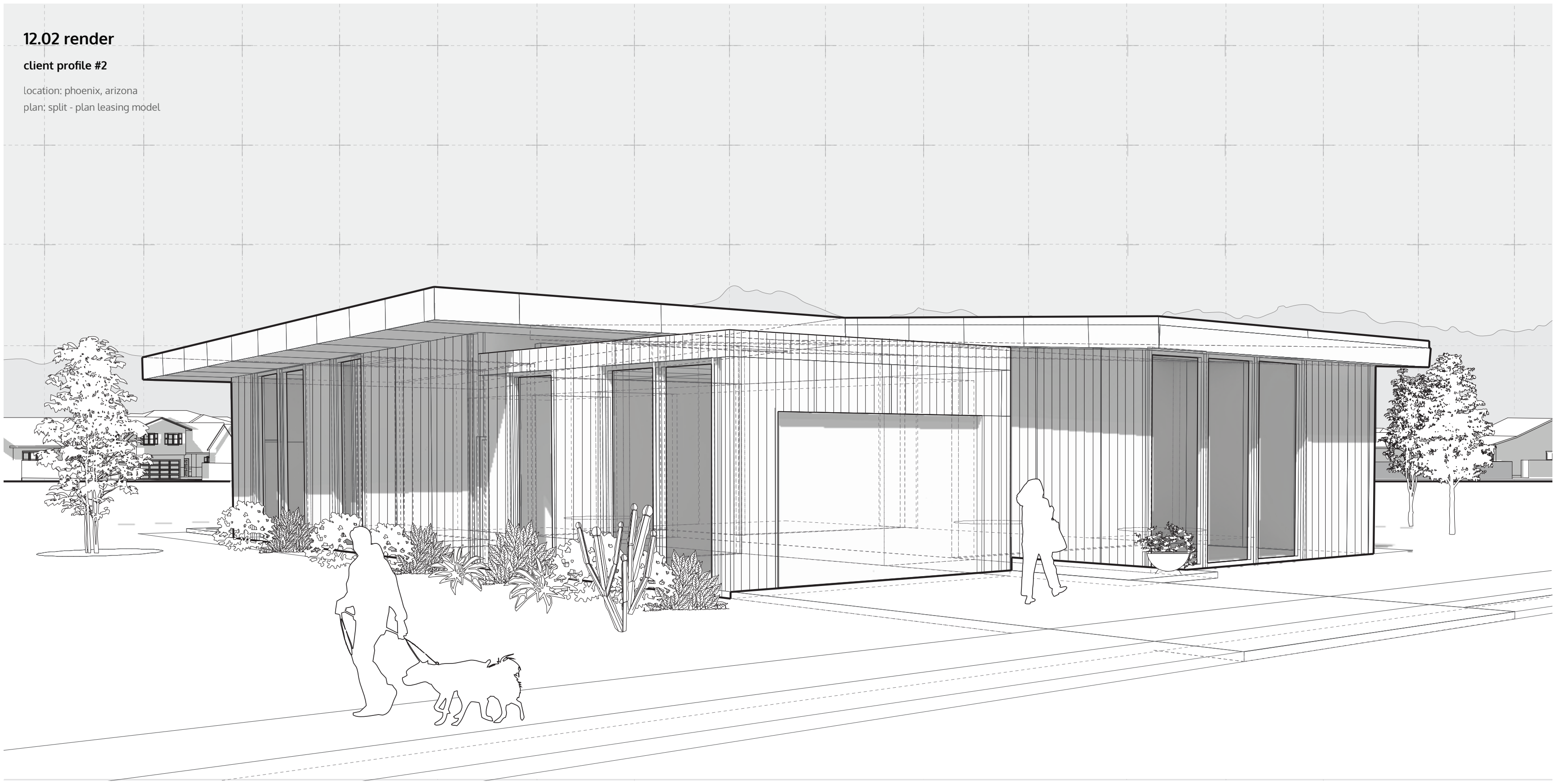

6.03 render
client profile #2
location: phoenix, arizona
plan: split - plan leasing model

6.03 section perspective

client profile #2

location: phoenix, arizona
plan: split - plan leasing model

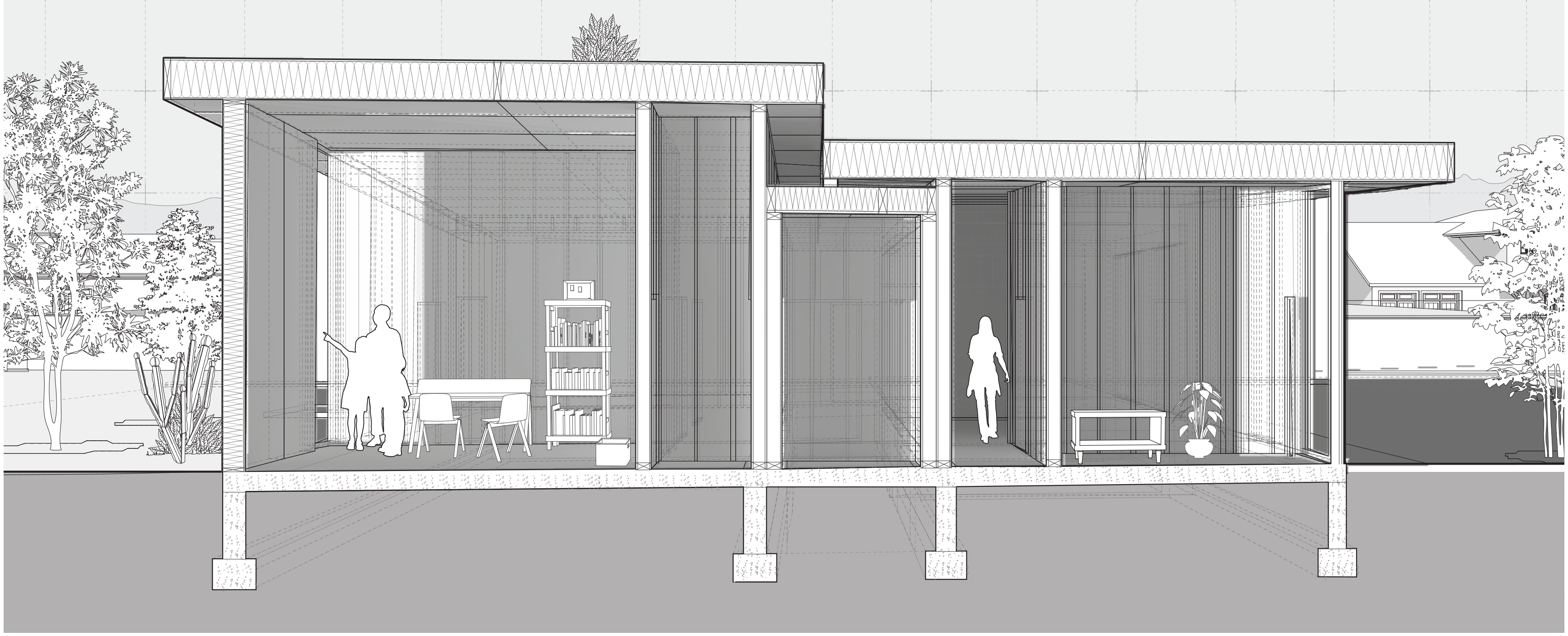



12.02 render
client profile #2
location: phoenix, arizona
plan: split - plan leasing model

12.02 section perspective

client profile #2

location: phoenix, arizona
plan: split - plan leasing model

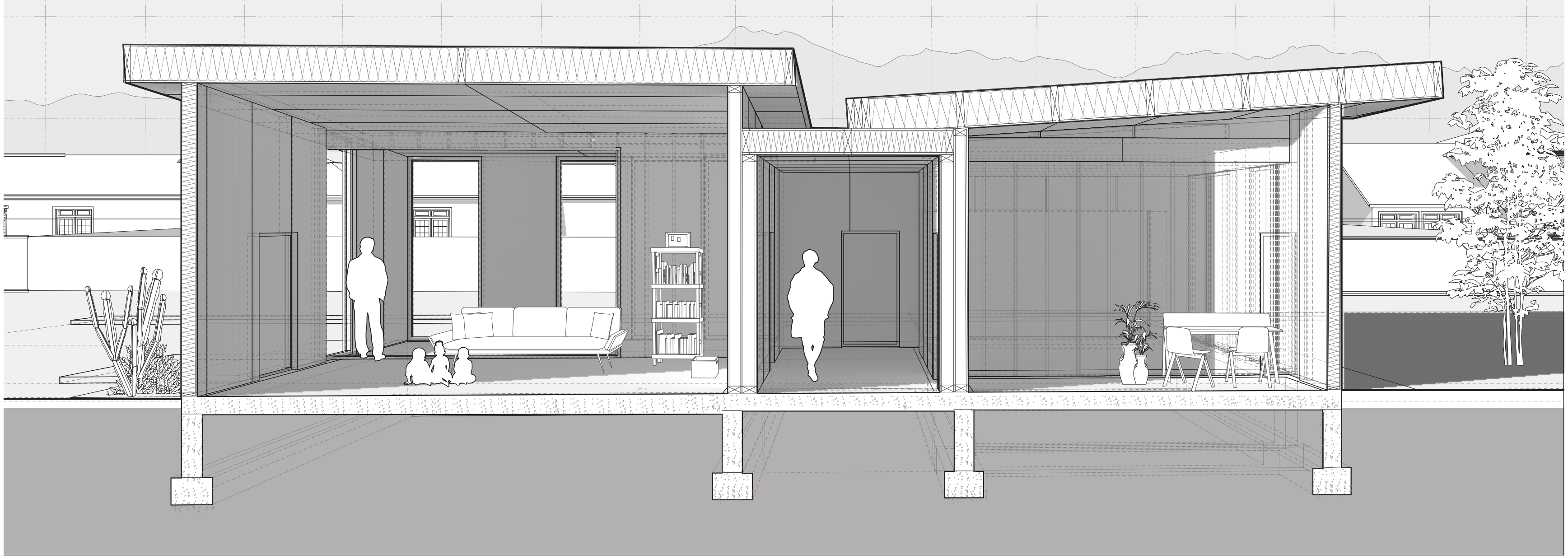


9.01 render
client profile #2
location: phoenix, arizona
plan: split - plan leasing model

9.01 section perspective

client profile #2

location: phoenix, arizona
plan: split - plan leasing model



06 / conclusions

The use of generative frameworks in the development of single - family housing successfully incorporates architects and ensures the variability of home designs, improved energy performance, greater customization to user needs, and home designs that are capable of responding to their immediate contexts.

Despite the benefits of multi objective optimization in suburbia demonstrated through this thesis, this workflow is not without limitations. Further research in this area would benefit in the development of further design considerations into the actual development of the framework, as the performance of the optimizations is still very much dependent upon the design that restricts it. If a framework were developed that performs well on its own, even greater performance and variation will be developed through its location and user dependent optimization. Additionally, it is crucial to maintain the incorporation of architects within this workflow, as this framework is a powerful design tool in the right hands but could potentially propagate the existing problems within suburbia if priority was given to objectives that only benefit developers and lenders. Lastly, through the development of this work, it is the opinion of the author that this work only be implemented on mass produced architectural typologies, due to both practical and theoretical constraints. Far more research is required in order to implement this type of workflow into uniquely designed buildings, as the amount of work that goes into the creation of this housing algorithm far outweighs its reward.

Despite these limitations and future opportunities, the use of architect - guided optimization in suburban mass production affords a foundation for growth and development toward environmental responsibility in an area that has recently faced responsibility for growing climate concerns. The generative framework workflow also revisits suburban design through its re-incorporation of architects, to ensure social equity in the design quality of single - family housing.

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